LIGHT DISCRIMINATION IN THE ENGLISH SPARROW

EUPHA FOLEY TUGMAN, A.M.

From the Psychological Laboratory of Indiana University

CONTENTS

I. INTRODUCTION

(1) *Statement of the problem.*—This investigation was pursued for the purpose of determining (1) the threshold of brightness discrimination in the house (English) sparrow, and (2) the behavior which the sparrow exhibits and the habits which it forms in learning to make such discrimination.

(2) *Previous experimental work.*—Considerable work has been done in experimenting on the learning. methods and capacities of animals, from amoeba to man. Only recently, however, have investigators begun to study the delicacy and completeness of the sensory equipment of animals. Of most importance in connection with the present investigation is the work of Breed,[1] Cole,[2] and Bingham[3] on chicks, and Porter[4,5] on birds.

Breed[1] used the discrimination method in experimenting with chicks. His results show that his chicks could discriminate between black and white, different colors, and two objects of different size. He made form tests also, but his chicks gave negative results.

Cole[2] used the discrimination method in studying " the relation of strength of stimulus to the rate of learning in the chick." His results seem to indicate that when discrimination is easy the number of trials necessary for learning is less than when the discrimination is difficult.

Bingham[3] experimented on size and form perception. His chicks were punished by electric shocks when they made a wrong choice, and were rewarded with " food, light, warmth, and companionship " when they discriminated properly and were thus able to reach their nest box. He found that " the chicks' threshold of difference in size perception lies between one-fourth and one-sixth when the diameter of the standard circle is 6 cm." He holds that " earlier experimenters on the chick's perception of forms have failed to eliminate all possible conditions for discrimination other than the factor of form. * * * Reactions to optical stimuli which have been interpreted by observers as indicating form discrimination are probably made on the basis of unequal stimulation of different parts of the retina. * * *

[1] Breed, F. S. The Development of Certain Instincts and Habits in Chicks. *Behavior Mono.*, vol. 1, No. 1, Nov. 1, 1911.

[2] Cole, L. W. The Relation of Strength of Stimulus to Rate of Learning in Chicks. *Journal of Animal Behavior*, vol. 1, No. 1, 1911. Page 111.

[3] Bingham, H. C. Size and Form Perception in Gallus Domesticus. *Journal of Animal Behavior*, vol. 3, No. 2, 1913. Page 65.

[4] Porter, J. P. A Preliminary Study of the English Sparrow and Other Birds. *Amer. Jour. of Psych.*, vol. 13, 1904. Page 313.

[5] Porter, J. P. Further Study of the English Sparrow and Other Birds. *Amer. Jour. of Psych.*, vol. 17, 1906. Page 248.

A chick can acquire a perfect circle-triangle reaction, but control tests show that it has no general idea of circularity in contrast with triangularity."

Bingham's conclusion is that " the order of importance of factors in the chicks vision is size, brightness and general illumination, and form."

Porter's[6] work is more directly related to the present investigation since he experimented with English sparrows. He first studied their method of approaching food, and found that they alight some distance from the food and then hop to it. He then studied their rate of learning to open a latch on a food box and of finding their way through a maze. He found that the sparrows learned quite rapidly by the trial and error method. They exhibited some ability to profit by experience, also to some extent by imitation. Porter then tested the number sense of the English sparrow in the same way that Kinnaman[7] did with monkeys. The birds could not count, but showed some sense of position. When the food glass was covered with colored papers of the standard yellow, blue, red, and green, the birds were able to distinguish the colors. Various forms of food boxes were then used and the food was placed in one of them, the position of which was changed from time to time. This test was made on one bird only—a female. She was unable to distinguish the forms.

In his later work Porter[8] experimented with English sparrows, vesper sparrows, a cowbird, and a pigeon, attempting to compare the rates and methods of learning of the different birds. In learning the simple maze the vesper sparrow was the slowest. There was little difference between the others. All showed good memories, the cowbird being best. With the puzzle box the sparrow learned most rapidly. Porter then tested the birds for discrimination of three horizontal black lines on a card from a blank card; a card marked with a black diamond from a blank card; and two marked cards from each other. Both the Eng-

[6] Porter, J. P. A Preliminary Study of the English Sparrow and Other Birds. *Amer. Jour. of Psych.*, vol. 13, 1904. Page 313.

[7] Kinnaman, A. J. Mental Life of Two Macacus Monkeys in Captivity. *Amer. Jour. of Psych.*, vol. 15, 1902.

[8] Porter, J. P. Further Study of the English Sparrow and Other Birds. *Amer. Jour. of Psych.*, vol. 17, 1906. Page 248.

lish sparrow and the cowbird learned to distinguish these designs, but the sparrow showed some superiority in being able the more quickly to unlearn an old habit and to learn a new one. In discriminating colors all the birds did about equally well, except the sparrow which showed superiority in the case of blue.

(3) *History of the investigation.*—(a) Preliminary experiment. This investigation was begun in the Psychological Laboratory of Indiana University on February 8, 1911. Twenty-six house sparrows were obtained but seventeen soon died. The experiment was begun with the nine remaining birds. Two birds were tested to see if they could be trained to choose the darker of the two stimulus areas. One was given 38 trials but chose the darker side only six times or 14% of the time. The other bird was given 32 trials and it chose the darker side 5 times, which is 14%. Then both birds died. The other seven birds were allowed to choose the brighter side which seemed to be the natural tendency. But the experiment was not continued very long as these birds also died. However, the few results obtained seemed to show that all the birds were able to discriminate the wide differences in intensities used.

The preliminary experiment was important in that it showed wherein the apparatus and method needed revision. One of the most important changes made in the apparatus was in the method of producing a motive. In the preliminary experiment the floor of the discrimination chamber was covered with parallel copper wires one centimeter apart. The wires were connected so as to form an interrupted circuit in connection with the induction coil and key. This was the plan used by Yerkes[9] in his experiments with the dancing mouse. But the sparrows rested with their feet in a sort of arched position with only the claws touching the wires. Consequently it was not easy to shock them. It was necessary to construct perches as described in a later section of this paper, and as used in the final experiment.

In October, 1911 the writer resumed the experiment with four birds,—two males and two females. The work continued until June, 1912.

---

[9] Yerkes, R. M., 1907. The Dancing Mouse. The Macmillan Co., N. Y.

II. METHOD

(1) *Care of the birds.*—The writer found it very difficult to keep sparrows alive in captivity. The birds were kept in a large cage before a large, open window in the experiment room. They were provided with an abundance of Spratt's mixed bird seed, fish bone, and clean water. The adjustable floors of the cage were cleaned frequently and covered with coarse sand. But for some unknown reason many sparrows died, usually in spasms. The experimenter found that the best plan was to cage the sparrows some weeks before beginning an experiment. If they died it was usually very soon after being placed in confinement. If they survived the first few weeks it was reasonably safe to begin an experiment with them. The four birds used in the final experiment kept in good physical condition until near the end of the investigation. One died in spasms shortly before the end of the experiment, and two others shortly after. The cause of death was not apparent. The fourth bird is still alive, after a confinement of one and a half years.

(2) *Method of handling the birds.*—In the preliminary experiments the writer tried handling the birds. This seemed to make them wilder, instead of taming them. To avoid the necessity of handling the birds the writer constructed a box 24 x 19.5 x 15 cm., and covered it with wire mesh. It was provided with a handle, and with a door at the end, and was used to transfer the birds from the cage to the apparatus. Against the back wall of each half of the cage was an inside adjustable wall of wire which, when pulled forward, forced the bird out at the door at the front, and into the portable box. Then the door of the box was closed and the bird carried about at will by the experimenter. This seemed to be a very good method of handling the birds as it did not frighten them after the first few times.

(3) *Description of the apparatus.*—The apparatus used in the investigation consisted of the Yerkes-Watson brightness apparatus,[10] and an experiment box modelled after the one described by these authors.[11]

---

[10] Robert M. Yerkes and John B. Watson. Methods of Studying Vision in Animals, pp. 17–24.
[11] Ibid, pp. 24–25.

The discrimination box is shown in Fig. 1 as that portion of the apparatus below the line EE¹ and marked DB. It is built of wood and blackened inside and out with several coats of lamp black and oil so as to make it a dull black. Very little light is reflected from the sides of the box. The box consists of an entrance chamber (C, Fig. 1) which is 5 x 4.5 x 19.5 cm.; the discrimination chamber is 54.5 x 46 x 19.5 cm., and is
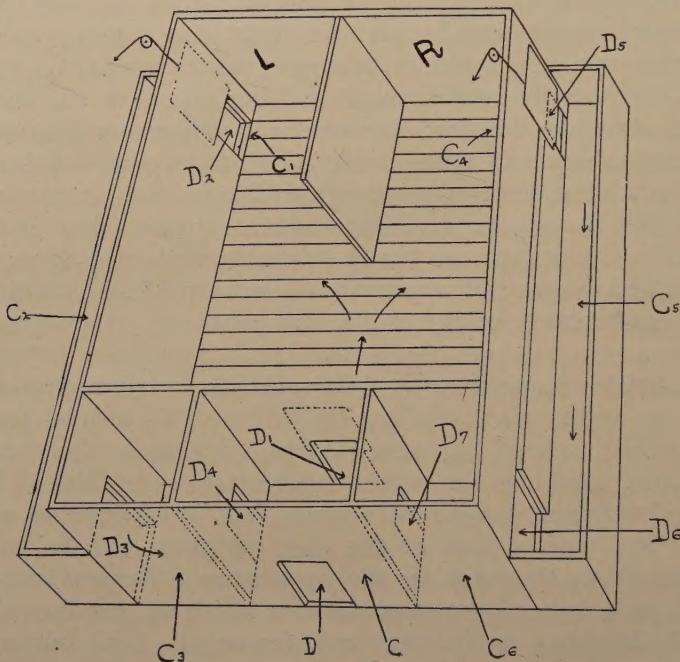
FIGURE 1. Discrimination Box. Openings indicated by D, chambers and alleys by C. Route of bird could be either C, D_1, C_1, D_2, C_2, D_3, C_3, D_4, C, or C, D_1, C_4, D_5, C_5, D_6, C_6, D_7, C. Discrimination made after passing through D. Cross lines in discrimination chamber indicate perches 2cm. above floor. Split brass tubes, stuck on wooden core with paraffine, form broken circuit which could be closed by bird grasping perch in alighting.

divided at the end next the light box by a partition 30 cm. long, into two identical compartments, C_1 and C_4. Alleyways, C_2 and C_3, which are 86 x 8 x 10 cm. connect C_1 and C_4 respectively with the compartments C_3 and C_6, both of which open into the entrance chamber C. These various compartments are separated by sliding doors D_1, D_2, D_3, D_4, D_5, D_6 and D_7, operated by

means of a system of cords and pulleys leading to the front end of the apparatus.

Two centimeters above the floor of the large discrimination chamber and four centimeters apart are perches across the box. The perches were made of three-eighth inch 22 gage brass tubing, oxidized and slit longitudinally into two halves. The two halves of this tubing were placed on either side of a .5 inch wooden core and held in place with paraffine. One-half of each perch is connected to one terminal and the other half to the other terminal of a Williams' Dial induction coil whose primary is in circuit with two dry batteries. A hand key is placed in the circuit and the secondary coil shifted to a position so that when a bird is resting on a perch it may be shocked by closing the circuit at the key. It is natural for the bird to hop from one perch to another and grip the perch with the feet. So when the feet are moist they can be shocked very effectively. A wet pad is kept in the entrance chamber C (Fig. 1) to keep the bird's feet moist. When dry the horny epidermis serves to protect them from the electric discharge.

The whole discrimination box is covered with .5-inch wire cloth, not shown in Fig. 1. The chamber C, and the near portion of C_1 and C_4 are covered with black velvet paper which prevents the bird from seeing the experimenter and the experimenter from seeing the bird until after the bird has discriminated and hopped to either C_1 or C_4.

(4) *Experimental procedure.*—Before beginning the experiments each bird was left in the discrimination box for twenty-four hours. All the doors were left open so that the bird could thoroughly acquaint itself with the apparatus. The use of artificial light for illuminating the stimulus areas made it necessary to conduct all the tests in a dark room. The birds were kept in the dark room so that they would not be excited by being moved from one room to another and also would become accustomed to the darkness and to the noise of the induction coil.

A small electric light in the room was turned off during each single test and then turned on again as soon as the bird had made its choice of the stimulus area and passed on into the alley.

On succeeding days (Sundays excepted) each bird was given a series of 15 trials. A trial consisted in requiring the bird to

discriminate between the two stimulus areas in order to return to the nest box without receiving a shock. · Two of the birds, Male V and Female VI, were required to choose the darker area and the other two birds, Male IV and Female V, were required to choose the brighter area. The two groups of birds were otherwise experimented upon in identically the same manner. Throughout the whole investigation the same order in shifting the lights was given to all four birds. The standard light was shifted to one side or the other at frequent and irregular intervals. The order was such that the standard light was on the left side the same number of times as on the right side.

Table I gives the relative position of the standard light during the first 225 trials. The other positions were similar to the ones shown in Table I. When the standard intensity (.098 c.p.) was in the position L (Fig. 1) the letter L was used. That means the standard was on the left. When the standard was on the right (at R, Fig. 1), the letter R was used. Since two birds were trained to go to the darker side L means for them that the darker light was on the left side and the brighter on the right. In the positions marked R the darker light was on the right and the brighter on the left.

TABLE I
Position of Standard Light for the First 225 Tests

Series	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Preference	L	R	R	R	R	L	L	R	L	L	..	..	..	..	..
1	R	R	L	L	R	L	R	R	L	R	R	L	R	L	R
2	L	L	R	L	R	L	R	R	R	R	L	L	R	L	L
3	L	R	L	L	L	R	R	L	R	R	R	L	R	L	R
4	L	R	R	L	R	R	L	L	R	R	L	R	L	R	L
5	L	R	L	L	R	R	L	R	L	R	R	R	L	R	L
6	L	L	R	L	R	R	L	L	R	R	R	L	R	L	L
7	L	L	R	L	L	R	L	R	R	L	L	R	R	L	R
8	L	R	R	L	R	R	L	R	L	R	L	R	L	R	L
9	L	R	L	R	R	L	R	L	L	R	L	R	L	L	L
10	R	R	L	R	L	R	L	L	R	L	R	L	R	R	L
11	R	L	R	L	L	R	L	R	L	R	L	L	R	R	L
12	R	R	L	L	R	L	R	L	R	R	L	L	R	L	R
13	L	R	L	R	L	L	R	R	L	R	L	L	L	R	R
14	L	R	R	L	L	R	L	R	R	L	R	L	R	L	R
15	R	L	R	L	L	R	L	R	L	L	R	R	L	R	L

The sources of light used were two 25 watt, 110 volt Mazda lamps, which were as near alike in quality of light as the experimenter was able to judge. The apertures in the stimulus adapter were 6 cm. in diameter.

The lamps were occasionally interchanged to prevent the birds from forming any habits due to difference in the quality of the light which the observer was unable to detect.   The discrimination box was frequently washed out as a precaution against the bird getting any "cues" or reflections due to the waste material which collected.

The procedure for each test was as follows: The bird was placed in the entrance chamber (C, Fig. 1) on the wet pad. The light in the room was then turned off and the induction coil started.   After waiting several seconds to accustom the experimenter's eyes to the darkness, the door D_1 was opened and the bird allowed to pass into the discrimination box.   (The entrance chamber was covered with black velvet paper and consequently was always dark.   Hence the bird's eyes were accustomed to the dark.)   Having entered it the bird could return to the entrance chamber only by passing through to the right or to the left of the partition and then through either door D_2 or D_3 and thence to C by way of the narrow alleys C_2 or C_3 through C_5 or C_6 and through doors D_4 or D_7 into the entrance chamber.   After passing through the door D_1 the bird nearly always hesitated several seconds and frequently several minutes, before making a choice between going to one or the other of the stimulus areas.   If the bird chose correctly it was allowed to pass on into the alleyway and back into the entrance chamber.   But if it made a wrong choice the circuit was closed at the key and the bird shocked.   The birds learned very soon that when they received an electric shock they must go back and around the partitions to the other side.   In the earlier experiments the birds would often stop just beyond the door D_1. In such cases the experimenter gave them instantaneous shocks which caused them to move on and thus force them to discriminate.   But after they learned what they were expected to do and discrimination became established, they would hesitate only a few seconds before making a choice.   In the later experiments it was seldom necessary to shock them except when they made a wrong choice.

A series of correct choices for two consecutive days—30 trials —was counted as correct discrimination and the difference in intensity of the standard and the variable light was decreased. At the beginning of the investigation the standard light was

placed at 38 cm. from the stimulus area, thereby giving it a measured intensity of .098 c.p. The variable light was placed at 238 cm. from the stimulus area, thereby giving it an intensity of .0025 cp.. After two consecutive days of correct choices the variable light was moved closer to the standard, which was always in the same position. Thus the intensity of the variable was increased each time, and the difference between the standard and the variable decreased in the same ratio. Each shift in the variable light necessitated the bird learning the problem again. It usually required a shorter time than the original problem, yet each shift was really a new problem to the bird. The difference between the standard and variable was decreased step by step until the bird was unable to discriminate between the two areas. Then the difference between the standard and the variable was increased step by step until the bird was able to discriminate between the two areas. The threshold of discrimination was taken as the difference between the least discriminable difference in the descending series and the least discriminable difference in the ascending series.

Full records were kept during the progress of each series, showing the relative positions of the standard light at each trial, the time consumed in making each choice, the success or failure of the trial, and full data regarding the actions of each bird during each trial. The characteristics of the individual birds, methods of learning, etc., and the tables and results are taken from these records.

(5) *Calibration of the lights.*—The light sources and the stimulus areas were calibrated near the beginning of and frequently during the investigation with a Lummer-Brodhun photometer against a Tungsten light, standardized at 1 c.p. in Hefner units.

The photometer readings were first taken with the light sources 38 cm.[12] back of the ground glass stimulus area. After the intensity of the stimulus area was calculated with the light source at this position, the intensities of the stimulus areas were calculated for the other positions of the light source.

The intensities shown in Table II are calculated from the

[12] The first experiments were made before this reading was taken. It was unfortunate that the light was not set nearer the glass and thus have given a reading of l.c.p. instead of the decimal .098.

readings taken on June 1, 1912, which was during the time that the birds were making the most difficult discrimination.

TABLE II

The figures in the first column indicate the number of discriminations required. The second column shows the c. p. of the standard light, calculated in Hefner units which remained the same throughout the experiment.   The third column indicates the c. p. of the variable light and the last column shows the difference in intensity between the standard and variable.

Position	Intensity of Standard	Intensity of Variable	Discriminated Difference
1	.098	.002	.096
2	.098	.003	.095
3	.098	.004	.094
4	.098	.006	.092
5	.098	.008	.090
6	.098	.010	:088
7	.098	.015	.083
8	.098	.019	.079
9	.098	.024	.074
10	.098	.043	.055
11	.098	.046	.052
12	.098	.048	.050
13	.098	.062	.036
14	.098	.065	.033
15	.098	.068	.030
16	.098	.073	.025
17	.098	.076	.022
18	.098	.081	.017
19	.098	.085	.013
20	.098	.089	.009

III. RESULTS

(1) *Threshold for discrimination.*—Table III shows the four sparrows' threshold of discrimination for the standard intensity .098.   The second column gives the least difference between the intensities of the standard and the variable illuminated areas

TABLE III

Showing the threshold of brightness discrimination for each of the four birds.

Bird	Least Discriminable Difference, Descending Order	Least Discriminable Difference, Ascending Order	Estimated Threshold
Male IV.......	.013	.017	.015
Female V......	.036	.033	.035
Male V........	Discriminating at .03 when he died	....	
Female VI.....	.022	.022	.022

which each sparrow was able to discriminate in the descending series. The third column gives the least difference which each sparrow was able to discriminate in the ascending order. The last column gives the average of these two which is taken as the threshold of discrimination for the standard .098 c.p.

(a) Comparison with human threshold. The experimenter, using the same apparatus and methods, investigated light discrimination in three human subjects in order to compare the results with those obtained with the birds. Two of the human subjects were required to choose the darker and one the brighter of the two stimulus areas. The subjects are spoken of as A, B,

TABLE IV

Comparison of brightness threshold for the four sparrows and the three human subjects.

Group	Subject	Estimated Threshold of Discrimination for the Standard Intensity=.098 c.p.
Bird	Male IV Female V Male V Female VI	.015 c.p. .035 " .03 (died) .022 c.p.
Man	A B C	.013 c.p. .009 " .013 "

and C. B gave very much better results all through the investigation than did either of the others and he responded to the darker of the two lights. C did not give very good results. He responded to the darker of the two lights. C was partially color blind and yet he was always seeing yellow or red in the lights. He said that the color in the lights confused him. This fact may have caused his poor results. The experiment with the human subjects was interrupted many times and often several days would elapse between successive series. This undoubtedly had some effect on the judgments. As the observers' time was limited, the work was not done as thoroughly or as completely as in the case of the birds. The thresholds are not absolute but are estimated from the limited data at hand. Table IV gives the estimated thresholds for both the birds and the

human subjects. There seems to be little doubt that for the particular intensity the human subjects have a very much smaller threshold of discrimination than do the birds. However, Male IV could discriminate almost as fine a difference in intensity as did two of the men. When the difference between the two lights became very small two of the subjects found that they were simply guessing and not really discriminating. Yet their results appear very good. So even from the results it is very difficult to determine just what their thresholds of discrimination are.

(2) *Methods of learning.*—The data which this investigation gives regarding the learning process of sparrows is fully as important as the light which it throws on the threshold of visual discrimination. More problems were of course raised than were answered, but much light is thrown upon many of the factors which condition animal learning and which in turn condition the sensory threshold which an animal may acquire. One of the most striking facts is the very large number of trials necessary to bring the animal to the threshold. The three animals for which the threshold was determined averaged 2420 trials each. For the discrimination of the lowest threshold they averaged 480 trials each; one of them discriminating only after 615 trials. This bird was trained daily, Sunday excepted, from April 8th until May 31 before she made a record of perfect choices for two days in succession.

(a) Tables and results for each bird. The results for each bird were tabulated in a regular form which stated the intensity (in Hefner units) of both the standard and the variable lights for each separate position; the difference between the intensity of the standard and the intensity of the variable; the date of each series; the number of each series; the number of right choices; the number of wrong choices; the number of times the wrong choices occurred when the standard was on the left; the number of times the wrong choices occurred when the standard was on the right; and the percentage of error for each series.

Male IV was allowed to choose the brighter of the two illuminated areas. The intensity of the standard was .098 c.p. and at the beginning of the experiment the intensity of the variable was .002 c.p. After each successful series of 30 choices the light was shifted.

On November 21st the difference in intensity between the
standard and the variable lights was shifted from .036 c.p. to
.022 c.p.   This seemed to be too large a step and confused the
bird, so on November 28th the difference was placed back at
.036 c.p. and the bird soon relearned that discrimination.   Then
when the difference in intensities was reduced in smaller steps
the bird learned to discriminate the lights with differences much
smaller than .022.   In the descending series the least discrim-
inable difference in intensity was .013 c.p.   When the intensity
was reduced to .009 c.p. the bird seemed wholly incapable of
discrimination and very soon fell into the position habit.   When
the intensity was increased to .013 c.p. the experimenter was
unable to break up the bird's position habit though it had dis-
criminated the lights at this position in the descending series.
Finally the lights were moved still farther back to .017 and after
14 days the experimenter succeeded in breaking up the position
habit.   The bird was again able to discriminate the illuminated
areas.   Hence the position midway between .013 and .017 c.p.
is taken as the least discriminable difference.   That position
gives the difference in intensity between the standard and the
variable as .015 c.p.   Of the 599 wrong choices the bird made
223 when the brighter light was on the right and 376 when it
was on the left.

Female V did not give as good results.   This the observer
attributed to the fact that she was always so frightened that
she would never hesitate long enough to make a discrimination.
She apparently had little position habit but simply went to one
side or the other in a confused manner.   She made the neces-
sary 30 consecutive correct choices with the difference in intensity
.036 c.p.   But when the position was shifted giving a difference
in intensity of .030 c.p. she was not able to discriminate even
after 540 trials.   So the variable light was moved back, in-
creasing the difference to .036 c.p. and after 600 trials she finally
made 30 correct choices.   Hence the least discriminable differ-
ence for Female V is .033 c.p.

Out of 434 wrong choices 305 were made when the brighter
light was on the right and 129 when the brighter light was on
the left.

For Male V and Female VI the problem was very much more
difficult.   They had to overcome their natural tendency to go

always to the brighter light, and learn to choose the darker light.   It took Male V 165 trials and Female VI 270 trials to learn the problem.   Table V shows the record made by the two sparrows in learning the problem.   The first column gives the number of each series of 15 trials.   The second and fifth columns give the average percentage of error (series divided into small

TABLE   V

Showing errors made in learning the first discrimination by the two birds which were trained to choose the darker light.   The middle column in each group shows the percentage of errors made in each test.   In the column to the left of the middle, the period of learning is divided into thirds and the average percentage of error is calculated for each third.   In the column to the right is given the percentage of error for each half of the learning period.   Despite occasional lapses as shown by increased percentage of error for single days, each of the later groups of days shows a decided lowering of the error percentage.   This shows the gradual aspect of the learning process.

	MALE V			FEMALE VI		
Number of Series	Average per cent of Error	Percentage of Error Daily Series	Average per cent of Error	Average per cent of Error	Percentage of Error Daily Series	Average per cent of Error
1		60			42	
2		40			42	
3	45	40	42.1	50.6	60	
4		40			40	
					60	44.8
5		40			60	
6		33				
7	38.7	42			40	
8		40			40	
					20	
9		0				
10		13		33.	66	
11	5.2	13	15.4		6	
12		0			26	
13		0				
					20	19.6
14					13	
15				16.5	26	
16					20	
17					0	
18					0	

groups) for Male V and Female VI respectively.   The averages show a decided decrease in the percentages of error made by the birds during the learning of the problems.   The third and sixth columns show the percentage of error for the daily series of 15 trials each, for each of the birds.   The fourth and last columns give respectively the average percentage of error for the first

half and the last half of the trials required to learn the problem. The figures also show a decided decrease in the percentages of error as the birds gradually learn the problem.

The curve (Fig. 2) is plotted from these results. The ordinates indicate the percentage of error and the abscissa, the number of the series—each series consisting of 15 consecutive trials. The solid line (————) is the error curve for Female VI and the broken line (- - - - -) for Male V, while learning to go to the darker side. The table and curve show that the sparrows varied in their daily record as well as in the time required to learn completely the problem. The table shows also that the
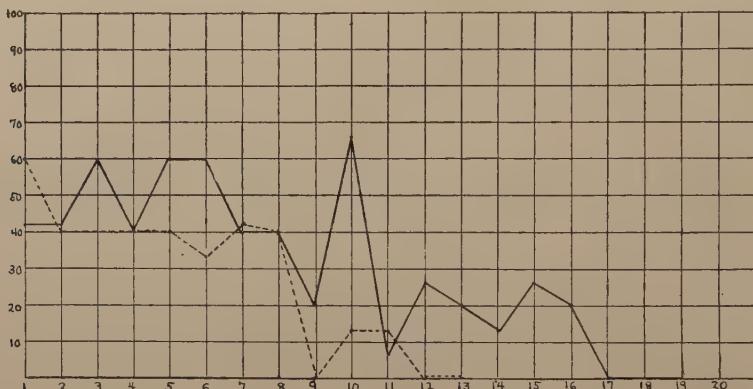

FIGURE 2. Curves showing percentage of errors made by two birds, Male V (- - - - -) and Female VI (————) while learning to choose the darker of two illuminated areas. Despite occasional lapses the learning appears to be a gradual process.

birds exhibited great instability even until the end of the experiment. Male V made one wholly perfect series of 15 trials—the ninth series. Female VI did not make a perfect daily record until the 30 correct choices were made in succession.

The progress of Male V toward the threshold was very slow. The observer felt that the bird really could discriminate the lights long before it gave perfect tests. But it was more hasty in making a choice than Female VI, with less attention and effort at discrimination. When Male V died he had been given 1515 tests and was working with the difference in intensities at .03 c.p. When Female VI had been given 1515 tests she was working with the lights at the discriminable difference .017 c.p.

Female VI had reached a point much nearer the threshold than had Male V after the same number of trials. Male V made 295 wrong choices, 184 when the brighter light was on the right and 111 when it was on the left. The observer had expected Male V to give better results than any of the other birds because he was in the same cage with the other birds and in the same room where the experiments were conducted for two months and a half before he was experimented upon. He did learn the problem more quickly than Female VI, but then fell behind her after the first change in the intensity of the lights. Male V died before the experiments were finished so his threshold of discrimination was not reached.

Female VI was a very satisfactory bird with which to work. After she once learned to choose the darker of the two illuminated areas, she would always stop just a few seconds outside the door (D₁, Fig. 1), look to one side and the other and then hop on calmly to the light she had chosen. She was never excited but always slow in her movements. She worked gradually toward the threshold. When the variable light reached 43 cm. with the standard at 38 giving a difference of intensity of .022 c.p. she discriminated immediately. The variable light was moved to 42 cm. thus giving a difference in intensities of .017 c.p. At this position she was given 720 trials, with 24 the percentage of error. But she apparently could not discriminate well enough to give two days of perfect trials. So the variable light was shifted back to 43 cm., giving a difference in the intensities of the lights of .022 c.p. At this point it took 450 trials before she gave 30 perfect trials in succession, while in the descending series she gave 30 perfect trials after having made only one wrong choice out of the 30 preceding trials. She had evidently been so puzzled with the lights when the difference in intensity was only .017 c.p. that she had either forgotten the problem or had formed the habit of not trying to discriminate. Whatever the cause it took her 450 trials to learn the problem which she had learned in the descending series in 30 trials. Out of a total of 414 wrong choices 262 were made when the darker light was on the right and 152 when it was on the left.

Hence the least discriminable difference for Female VI was .022 c.p., a difference of 5 cm. between the position of the standard and the variable light.

(b) Comparison of results. Table VI shows a summary of the results for each bird. The first column gives the difference in intensity (c.p. Hefner units) between the standard and the variable lights in the decreasing series. The third column gives the number of trials it took each bird to learn to discriminate the lights at each position. The fourth column gives the number of correct choices and the sixth column gives the number of incorrect choices. The last gives the percentage of error of each bird for each intensity.

TABLE VI

Summary of results for each bird. Male IV and Female V chose brighter light Male V and Female VI chose darker light. Male V began discrimination with lights nearer together than did the other birds.

Difference in Intensity (Hefner Units) between the Standard and the Variable Light	Bird	Number of Trials	Right Choices	Wrong Choices	Per cent of Error
.096	Male IV....	30	30	0	0
	Female V...	30	30	0	0
.095	Female VI..	240	150	90	37
.094	Male IV....	30	30	0	0
	Female V...	45	42	3	6
	Female VI..	15	13	2	13
.092	Male V.....	75	70	5	15
	Female V...	90	84	6	6
	Female VI..	30	30	0	0
.090	Male IV....	30	30	0	0
	Female V...	30	25	5	16
	Female VI..	15	14	1	6
.088	Male IV....	30	30	0	0
	Female V...	30	30	0	0
	Female VI..	75	65	10	13
.083	Male IV....	30	30	0	0
	Female V...	30	30	0	0
	Male V.....	165	113	52	31
	Female VI..	15	14	1	6
.079	Male V.....	30	30	0	0
.074	Male IV....	30	28	2	6
	Female V...	15	10	5	33
	Male V.....	30	30	0	0
	Female VI..	30	30	0	0

TABLE   VI—*Continued*

Difference in Intensity (Hefner Units), between the Standard and the Variable Light	Bird	Number of Trials	Right Choices	Wrong Choices	Per Cent of Error
.055...............	Male IV....	30	30	0	0
	Female IV..	135	85	50	37
	Male V.....	420	329	91	21
	Female VI..	30	23	7	23
.052..............	Male V.....	210	146	64	31
.050..............	Male V.....	180	151	29	16
.036..............	Male IV....	90	66	24	27
	Female V...	45	41	4	8
	Male V.....	120	86	34	28
	Female VI..	15	14	1	6
.030..............	Male IV....	30	0	0	0
	Female V...	540	415	125	23
	Female VI..	285	229	56	20
Back at .033.......	Female V...	600	496	104	17
.025..............	Male IV....	15	14	1	6
	Female VI..	30	0	0	0
.022..............	Male IV....	90	66	24	27
	Female VI..	30	29	1	3
.017..............	Male IV....	225	181	44	19
	Female VI..	720	557	163	22
Back at .022.......	Female VI..	450	....	....	....
.013..............	Male IV....	315	239	76	24
.009..............	Male IV....	390	341	49	12
Back at .013.......	Male IV....	360	306	54	15
Back at .017.......	Male IV....	240	165	75	31

The following figures are made from this table. Figures 3 and 4 show the number of trials each bird required to learn to discriminate the light at the given intensity. The abscissae indicate the differences of intensity produced by the standard light and the various positions of the variable light. The ordinates indicate the number of trials required to learn the discrimination. Figure 3 gives the results for Male IV and Female V, both of which were allowed to choose the brighter of the

two stimulus areas. The solid line (————) is the curve for Male IV and the dashed line (- - - - -) is the curve for Female V.

Figure 4 gives the results for Male V and Female VI. The solid line (————) represents the results for Male V. The abrupt ending is due to the bird dying at this point in the investigation. The dashed line (- -.- - -) represents the results for Female VI. Both Male V and Female VI, as stated before, were trained to choose the darker of the two illuminated areas. The curves for Male IV and Female V (Figure 3) are not widely different until the threshold was reached for Female V. They
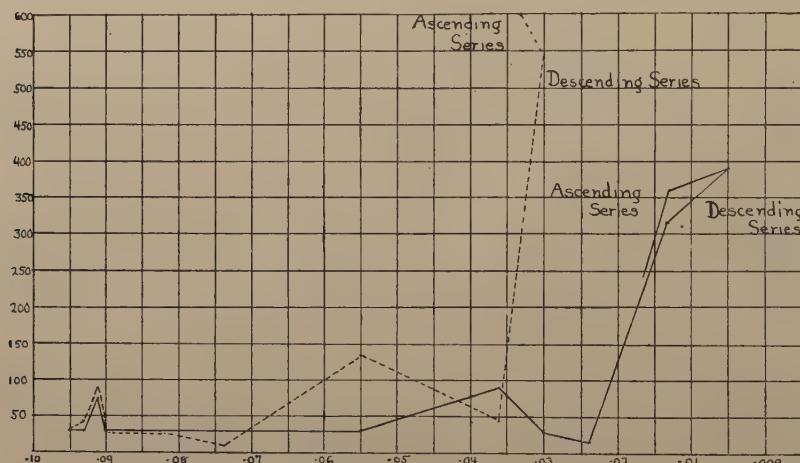

FIGURE 3. Number of trials necessary for Male IV (————) and Female V (- - - -) to learn each discrimination. The difference in intensity is shown on abscissae. Number of trials is represented on ordinates. Both curves show large number of trials necessary when difference in intensity is small.

begin practically the same. Both birds had little trouble in discriminating the areas when there was a wide difference in the intensities. When the difference in intensity was .055 c.p. Female V required 135 trials while Male IV made 30 perfect choices without any trouble. Then at the difference in intensity of .036 c.p. Female V made a better record than Male IV. But when the variable light was again shifted and the difference in intensity reduced to .030 c.p. Female V seemed wholly incapable of discriminating even after 540 trials. The difference in intensity was increased to .033 c.p. and after 600 trials she discriminated. For the descending series Female V had discrimi-

nated this same intensity after 135 trials.   But when she failed with the difference in intensity .030 c.p. she seemed to have gotten into the habit of immediately going to one side or the other without any effort at discrimination.   Consequently when the difference in intensity was later increased it took a long time to break up this habit.   Male IV continued to discriminate the lights without hesitation until the difference in intensity was decreased to .025 c.p.   Then the curve starts up abruptly.   This
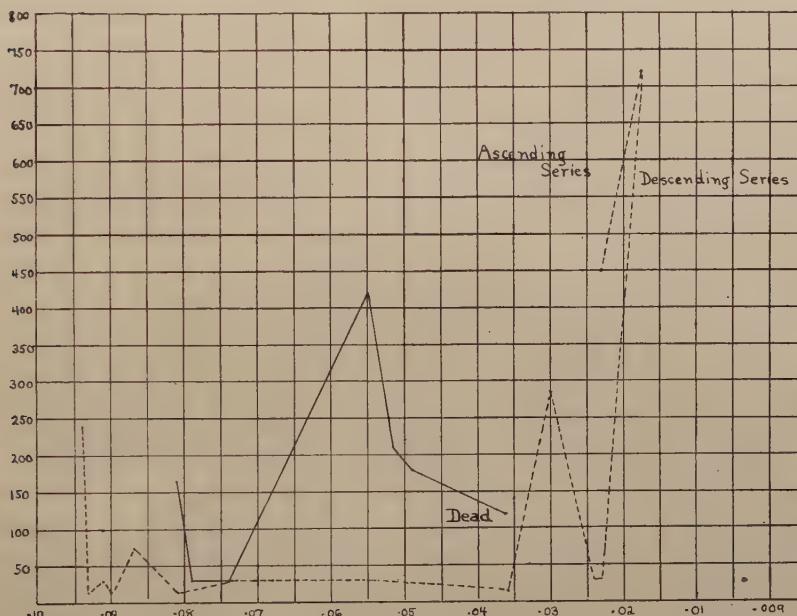

FIGURE 4.   Number of trials necessary for Male V (———) and Female VI (- - - - -) to learn each discrimination.   The difference in intensity is shown on abscissae.   Number of trials is represented on ordinates.   Curve for Female VI shows large number of trials necessary when difference in intensity is small.

shows that as the discrimination became more difficult, the bird required more trials to learn the discrimination.   But when the difference in intensity of the illuminated areas was reduced to .009 c.p. Male IV was unable to learn the discrimination even after 390 trials.   The difference in intensity was increased to .013 c.p.   At this position he finally succeeded in learning the discrimination after 315 trials.   But in the ascending series he was not able to learn to discriminate correctly even after 360 trials.   The difference in intensity was increased to .017 c.p.

and after 240 trials he succeeded in giving 30 correct choices. The observer felt that the bird could discriminate the areas when the difference in intensity was .013 c.p. But when he was on the .009 intensity he acquired the position habit which lasted through the 306 trials at the next position and almost until the end of the investigation.

Figure 4 represents the results of Male V and Female VI. The curves are more irregular than those for Male IV and Female V. The curve of Female VI is more nearly like those of Male IV and Female V than is the curve of Male V. The sudden drop in both curves indicates the fact that both birds learned to choose the darker of the two illuminated areas. After Female VI learned the first discrimination she had no trouble until the difference in intensity became small. She readily discriminated a difference in intensity of .022 c.p., but when the difference was reduced to .017 c.p. she was incapable of discriminating the areas even after 720 trials. The difference in intensity was then increased to .022 c.p. and after 450 trials she succeeded in discriminating the lights.

Male V learned to go to the darker of the two illuminated areas more quickly than did Female VI, but his other results were never so good as those of Female VI. The observer felt that the discrimination was really not difficult for the bird but that many of his wrong choices were due to fright. He often did not even attempt to discriminate the lights. He would go to one light and if he failed, would hurry around to the other side and into the alley way. He was beginning to give better results when he died.

(3) *Incidental results.*—The author has included under this heading some of the most interesting facts brought to light during the experiment with the birds.

(a) Individuality. As shown in the previous discussion, the sparrows exhibited distinct individual differences in their rate of learning. This was also true of their general behavior and of their method of attacking the problem. The individual birds also varied their course of procedure at intervals during the experiment.

All the birds were quick in learning the apparatus and its various alleyways. When they chose the wrong light and were

shocked they very soon learned to turn and go around to the other light. They were slower to learn to enter the alleyways because they were dark and the bird avoids dark places. But even this natural tendency was overcome in a surprisingly short time.

The directness or indirectness of approach and entrance into the discrimination box varied in the different cases. Two of the birds would hesitate several seconds or even minutes before entering the discrimination box. But the other two seemed eager to go through the experiment. Male IV was calm and deliberate in his movements. He would hop into the doorway (D_1, Fig. 1) as soon as it was opened. He would sit in the doorway or just outside for several seconds, turning his head quickly to one side or the other. (All the birds looked at the lights with their heads turned to one side or the other. They never seemed to look at the lights with both eyes at the same time.) Then he would hop calmly on, to whichever light he had chosen. He never seemed excited and seldom required shocking. When shocked it required a heavy discharge to produce any effect.

Male V was always very much excited. For a long time he would dart out to one side or the other without attempting to discriminate the lights. Suddenly he changed his method and would hesitate a long time just beyond the door (D, Fig. 1). There he would sit, often for several minutes. Sometimes the observer would have to shock him before he would move. But usually after a long hesitation he would dart on to one light or the other. The observer felt that as a usual thing he did not rely upon visual discrimination. His judgments were never very satisfactory.

At the beginning of the experiment Female V would always hesitate in the doorway, discriminate between the lights and hop on. But later she acquired the habit of darting out to one light or the other the very instant the door was opened. For a long time it seemed absolutely impossible to break up this habit. Frequently there would be days when the bird seemed to show some improvement but in general she gave very poor results. Finally the observer decided that she did not have such good sight as the other birds and that she had really reached her threshold of discrimination. The difference in the intensity of the lights was increased a little and after a short time the

bird began to discriminate them again. The previous behavior was evidently due to inability to make the discrimination.

Female VI was more calm 'than any of the other birds. Her behavior was even more satisfactory than the behavior of Male IV. After Female VI learned the first problem, to choose the darker of the two lights, she would move about very slowly and deliberately. She would hesitate in the doorway of the entrance chamber for a few seconds, then hop out into the discrimina-' tion box. She would hesitate several seconds looking a while to one side, then turning her head and looking to the other side. Presently she would hop on to the side she had chosen and into the alleyway. She was always slow making a choice and gave good results all through the experiment.

The nervous birds gave the poorer results.

Cole[13] thought the chicks which were most sensitive to the electric shock learned more rapidly under the influence of weak stimuli. The most sensitive sparrows did not learn most quickly. The two birds which gave the best results, Male IV and Female VI, both required a heavier shock than the other two birds. It was not necessary to shock them frequently. But when it was necessary, the observer had to give them almost twice the strength of current that was given the other birds. As stated before, the final results differed widely. Male V and Female V failed to discriminate lights with which the other birds had no difficulty. The observer thinks that Male V and Female V were inferior to the other two birds in acuteness of vision and probably in mental capacity also.

(b) Influence of former experiences. At first the birds were greatly influenced by their former experiences. They would tend to respond in the same direction as in the immediately previous test, provided they had not received a shock. If they had just received a shock they would nearly always go to the other light in the following test. But after the birds learned the problem their judgments were founded on visual discrimination and they were not guided much by previous experience except when they acquired the position habit.

(c) Position habit. The thing that gave the experimenter the most trouble was the tendency of the birds to get the posi-

---

[13] Cole, L. W. The Relation of Strength of Stimulus to Rate of Learning in Chicks. Journal of Animal Behavior, Vol. 1, No. 1, 1911. Page 111.

tion habit.   The habit might appear at any time and the ob-
server always had to be alert lest the habit get firmly fixed.   If
it did become fixed it was very difficult to break.   It is evident
the sparrow forms the habit of choosing by position much more
easily than the habit of choosing by visual discrimination.   The
form of position habit which appeared most frequently was that
of alternating from one side to the other without regard to the
illumination.   But the observer found that the birds learned
also to go twice to one side, then twice to the other side, etc.
A few times when the order required three choices in succession
to one side, the birds would invariably want to go three times
to the other side.   The experimenter planned to try more com-
plicated orders and see if the birds could be trained to learn the
habit.   Lack of time prevented her carrying out this part of
the investigation.

(d) Mental instability.   The sparrows exhibited three quite
distinct types of mental instability; all of which were sources
of considerable trouble to the observer.   At times the birds
would go to one side or the other apparently without trying to
discriminate.   This is the first type.   The second type of mental
instability was the persistence in going to one side.   When they
would persist in this the experimenter found it quite impossible
to do anything with them.   The third type might be termed
stubbornness or stupidity.   When they would get stubborn or
stupid they would simply refuse to move.   They would pay no
attention to an electric shock.   The observer would force them
around through the apparatus though the results obtained on
such days were useless.

The experimenter noticed that all the birds seemed to have
these periods of mental instability though they did not all have
them at the same time.   One day a bird would record an almost
perfect series and the very next day a series of failures.   It was
noticeable that such stupidity nearly always succeeded a period
of unusually good work on the part of the bird.   The bird usually
recovered from this stupidity as quickly as it had come on.
Then the bird would continue the usual method of procedure as
though nothing unusual had happened.   A few times they re-
covered during a day's series and the last few results would be
very satisfactory, while the first of the series were failures.
The question which came to the mind of the experimenter was

whether or not these periods of stupidity or stubbornness come at regular intervals. But she was unable to decide from the data at hand.

(e) Relation of time to failure or success of judgment. The human subjects thought that the hasty judgments were more often correct than the deliberate ones. The observer, as stated before, kept account of the time required to make each choice. Then she averaged about 500 of these times for each bird. The 500 times were taken as representative of the total data. They include the time required to make the choice for each of a day's series selected at intervals throughout the whole experiment. These times were averaged—the time of the correct choices in one column and the time of incorrect choices in another column. The results are shown in Table VII.

TABLE VII

Relation of time of choice to failure and success of judgment. Average of 500 choices taken at random throughout the experiment. Correct choices required less time than incorrect ones except in case of Female V, all of whose choices were very rapid.

Male IV
Time of correct choices.................average 28 seconds.
Time of incorrect choices...............average 30 seconds.
Female V
Time of correct choices.................average 18 seconds.
Time of incorrect choices...............average 17 seconds.
Male V
Time of correct choices.................average 31 seconds.
Time of incorrect choices...............average 47 seconds.
Female VI
Time of correct choices...........average 1 min. 20 seconds.
Time of incorrect choices.........average 1 min. 49 seconds.

Female V made the quickest choices and gave the poorest results. Male IV gave the best results and made rather hasty judgments. Female VI gave the next best results and was the slowest of them all in making her choices.

It is noticeable that, with one exception, the time required to make the choice was shorter for the correct choices and longer for the incorrect choices. This coincided with the opinion of the human subjects.

However, there were too few birds experimented upon to draw any definite conclusions as to the relation of the time required to make a choice and the success or failure of the judgment. This is a most interesting problem for further investigation.

TABLE VIII

All records for the day before and the day after a forty-eight hour interval.   The day before was usually Saturday; the day after Monday.   The average for the day after is in every case greater than that for the day before the long interval.

MALE IV		FEMALE V		MALE V		FEMALE VI.	
Per Cent of Error		Per Cent of Error		Per Cent of Error		Per Cent of Error	
Saturdays	Mondays	Saturdays	Mondays	Saturdays	Mondays	Saturdays	Mondays
0	6	0	6	60	40	90	90
13	6	13	0	33	46	10	40
0	0	6	6	0	0	20	40
0	0	0	20	0	13	30	0
0	0	13	6	6	0	0	0
0	53	0	33	26	13	6	13
46	60	60	26	20	26	13	0
40	33	40	26	20	33	0	0
33	26	26	46	26	26	6	0
0	0	26	46	20	26	46	26
33	26	20	33	26	13	0	20
6	53	33	13	20	13	13	20
0	26	0	26	20	40	20	20
26	26	26	40	40	40	6	0
26	26	33	33	46	46	0	0
26	20	0	46	13	33	13	6
26	20	46	13	13	0	0	20
33	20	0	20	26	26	33	20
26	0	0	13	0	13	13	26
40	53	0	0	0	0	26	20
40	53	33	0	20	40	6	33
33	20	6	40	13	0	13	26
20	46	40	33	33	40	26	20
40	46	20	33			26	26
53	46	20	13			13	0
40	53	13	26			0	20
46	33	0	20			0	26
33	46	20	26			13	20
46	6	26	13			33	20
53	33	13	26			20	40
40	53	26	0			40	13
53	33	13	20			0	26
33	33	13	20			0	6
13	26	26	40			0	0
		0	26				
		6	6				
		6	13				
		0	26				
		0	0				
Ave. 26.97	Ave. 28.8	Ave. 15.81	Ave. 21.35	Ave. 20.91	Ave. 21.91	Ave. 15.73	Ave. 18.73

Difference between Saturday and Monday record.

1.83   5.54   1.00   3.00

(f) Effect of 48 hour interval between successive series. Table VIII shows the effect of 48 hours interval between successive series. As stated before, one series per day was given each bird except on Sunday and an occasional holiday. So this table gives the percentages of error for the series on the day preceding the holiday and the percentage of error for the day succeeding the holiday. In a few cases the position of the variable was changed over the holiday and so these cases were not considered.

For Male V the average percentage of error for Saturday and days preceding holidays is 26.97, while for the day following the 48 hours' rest, his percentage of error is 28.8 or an increase of 1.83%. For Female V the average percent of error for Saturday, etc., is 15.81% and for Monday the average is 21.35%, which shows an increase of 5.54%. Male V has an average per cent of error on Saturday of 20.91% and on Mondays an average per cent of error of 21.91%, which is an increase of just one per cent. Female VI has an average per cent of error on Saturdays of 15.73% while on Mondays her average per cent of error is 18.73%, which shows an increase of three per cent.

To recapitulate: For Male VI Mondays show an increased percentage of error of 1.83%; Female V, 5.54%; Male V, 1%; and Female VI, 3%. Thus each of the birds shows the effect of an extra 24-hour interval between two series, by an increase in the average percentage of error for the following day.

(g) Persistence of stimulation. It has been the experimenter's observation that the sparrows do not retain the effects of stimulation very long at a time. Frequently, as stated before, the birds would get the position habit of alternating from one side to the other. One day, when this occurred, the series was interrupted as the experimenter was called out of the room. Upon returning to the experiment the observer noticed that the bird hesitated before choosing between the lights. He then chose the same light as in the test preceding the interruption. Then in the following tests he alternated from one side to the other as before. So the alternation was in regular order with the exception of the one break due to the interruption. After that when a bird acquired the habit of alternating from one side to the other, the observer would stop the experiment several minutes. In practically every case the bird would hesitate in making a choice in the test following the interruption and usually

this caused a break in the order. It looked as though he had forgotten which light he had chosen before. It would be interesting to experiment further in detail upon this question. But from the very limited material at hand, the observer is inclined to think that the birds do not retain visual impressions very long at a time.

IV. QUESTIONS SUGGESTED BY THIS INVESTIGATION.

The question arose as to whether or not the birds would have reached their threshold of discrimination in less time if the intermediate steps were omitted. That is to say—train the bird to discriminate the lights with wide differences in intensity. Then make the difference very small and see if the bird could not learn to make the discrimination in less time than was required to pass through all the intermediate steps. The observer thinks that a great number of the intermediate steps might be omitted in the earlier part of the experiment when the differences in the intensities of the lights were large. Female VI and Male V were trained to choose the darker of the two lights. Female VI learned to choose the darker of the two lights when they were 162 cm. apart, which made the darker of the two lights very dim. Male V learned to choose the darker of the two lights when they were 60 cm. apart and learned the problem in a shorter time than did Female VI. It might have been better to have omitted all the work with the wide difference in intensity for Female VI and begun where Male V began. The results of Male V might have been due to the fact that the darker of the two lights was not so dark as it was for Female VI. It may have been easier for the bird to learn to choose a light of medium intensity, than it was for Female VI to learn to choose a light of extremely low intensity. However, the small steps seemed to be essential as the birds neared the threshold. In one case the observer decreased the difference in intensity too much by one step. The bird seemed absolutely unable to make the discrimination after it had been at the problem a long time. But when the lights were shifted back to their former position and then the difference in intensity decreased step by step, the bird experienced no difficulty in making even finer discriminations. So it seems that the tests at intermediate intensities were essential and that practice was an important factor in learning.

Another question was raised. When perplexed for a long time does the bird forget or unlearn the problem? The observer is inclined to think that it does.

Male IV learned to discriminate the lights when the difference in intensity was .017 c.p. after 225 tests. The difference in intensity was decreased to .013 c.p. and he learned the discrimination in 315 tests. The difference was again decreased to .009 c.p. The bird was completely perplexed. Each time he went to the right side. 390 tests were given him but he could not learn to discriminate so small a difference in intensity. The variable light was shifted back so the difference in intensity was .013 c.p. He had correctly discriminated this difference before in 315 tests. But now he continued to go every time to the right side. After 360 tests the difference in intensity was again increased—this time to .017 c.p. He had previously learned this discrimination after 225 tests. The bird still persisted in going to the right side. The observer finally decided that the bird had forgotten the problem. So the difference in intensity was made extremely large. The bird correctly discriminated the lights in 15 tests. The lights were then shifted back to .017 c.p. and the bird took 240 trials in learning the discrimination which had only required 225 trials in the descending series. The results therefore, seem to indicate that the bird was perplexed so long that he really forgot or unlearned the problem.

Another question which suggested itself was whether or not the birds would learn the position habit if the order was very complicated. They soon acquired the habit of alternating from right to left. A few times the experimenter observed that the birds learned to go twice to one side and twice to the other and three times to one side and three times to the other. These latter cases might have been merely accidental. It would certainly be an interesting problem to try various orders and see if the bird could learn them. Also, could the bird acquire the position habit if it did not have the light to guide it, i.e., if the lights were of equal intensity?

The observer is very much interested in the question of whether or not these periods of stubbornness or stupidity, which all the birds seem to have occasionally, occur periodically. She was unable to tell from the data at hand.

Before concluding the author wishes to express her deepest appreciation of the valuable suggestions, criticism and encouragement of Dr. M. E. Haggerty, who so kindly suggested and directed this experiment.   She is also greatly indebted to Dr. Haggerty, Mr. William O. Trapp and Mr. George H. Hyslop, who were the human subjects in this investigation.

THE ROLE OF RANDOM MOVEMENTS IN THE ORIENTATION OF *PORCELLIO SCABER* TO LIGHT

HARRY BEAL TORREY and GRACE P. HAYS
Reed College, Portland, Oregon

1

In his admirable paper on " The Selection of Random Movements as a Factor in Phototaxis," Holmes[1] has given great significance to random, that is, spontaneous, non-directive movements in the orientation of earthworms, blow fly larvae, and leeches, to light. As he carefully watched the movements of these organisms under the influence of light, it " soon developed that what seemed at first a forced orientation, the result of a direct reflex response, is not really such, but that the orientation which occurs and which is often quite definite is brought about in a more indirect manner by a mode of procedure which is in some respects similar to the method of trial and error followed by higher forms." The organism becomes oriented by following up those random movements which bring them away from the source of light.

While our experiments on the larvae of an undetermined species of blow fly and on a species of earthworm (*Allolobophora* sp.) materially lessen for us the importance of random movements as a factor in the orientation of these organisms to light, our conclusions are in complete accord with Holmes' view that the type of reaction he describes " differs from Jennings' ' motor reflex'' by which many of the so-called tropic reactions are produced in the Protozoa." This difference has little significance for Mast[2] who believes that " the only difference between the orienting reactions in the two classes of animals mentioned is that the unicellular forms studied by Jennings always turn toward a structurally defined side, while the metazoa investi-

---

[1] Journal of Comparative Neurology and Psychology, 1905, No. 15, p. 18.
[2] Light and the Behavior of Organisms, 1910, p. 51.

gated by Holmes are not thus limited in their direction of turning."

In thus minimizing a difference to which Holmes has explicitly called attention, Mast may have missed a cardinal point in Holmes' illuminating discussion. The direction of the random movements of the blow fly larvae as observed by Holmes is not predictable so far as it bears no definite relation to the source of light. The direction of the movements of *Euglena*, an organism in which the "motor reflex" plays an important part in its orientation to light, *is* predictable, since it *does* bear a definite relation to the source of light. In the one case, the orienting movements, made at random, are not controlled, as to direction, by the light; in the other case, the orienting movements are definitely controlled, as to direction, by the light. In the former, selection operates among so-called trial movements; in the latter, in so far as the movements are controlled or forced by an external agency, the method of trial is excluded. This difference, then, is of no little significance in an attempt to determine—as this paper is attempting to determine for certain organisms—the actual value of the orientation hypothesis that rests upon the assumption of trial movements.

2—

The fact that some authors do not distinguish between random movements and directive movements forced by the environment has been a source of some confusion in the literature of animal behavior. Further confusion has centered about the conception of symmetrical stimulation repeatedly emphasized by Loeb and recently reaffirmed by Parker.[3] Investigators of the orienting reactions of non-symmetrical protozoa or symmetrical organisms such as rotifers and worm larvae that swim, like the protozoa, in spiral courses, have had difficulty in seeing the applicability of this conception to their material. That the conception is applicable, however, to the behavior of such organisms as *Euglena*, though not in the form apparently anticipated by some of its critics[4] a recent paper[5] has attempted to show. And its applicability to the orientation of earthworms and blow

[3] Journal of Animal Behavior, 1911, No. I, p. 461.
[4] Mast, 1910, p. 85.
[5] Torrey, Science, No. 38, p. 873.

fly larvae to light has been convincingly discussed by Parker in the paper just mentioned.

These conceptions of symmetrical stimulation and of forced directive movements have long characterized the tropism hypothesis, whatever other attributes it may be said to possess; and they appear to be quite inconsistent with the conception of orientation by the selection of trial reactions. There should be little danger of confusion, then, in designating as tropic reactions not only the very gradual turning movements that may or may not be connected with tonic contractions accompanying constant stimulation, but also the more abrupt and angular turning movements composed of a series of forced shock reactions, *all in the same general direction*, that we have repeatedly observed in the orientation of *Euglena* to light. Both extremes are, in fact, represented in the behavior of *Euglena*, which will be considered in another paper. Whether they also represent two different mechanisms of orientation is a question for the future to decide.[6] That they do not involve the selection of random movements there appears to be no doubt.

In the following account of the reactions of *Porcellio scaber*, it will be seen that although random movements are common they can readily be distinguished from the forced movements that occur in definite predictable directions in response to differential stimulation of symmetrically situated photoreceptors. But such phototropic movements not only exist; they are *large factors* in the orientation of *Porcellio* to light. This is true also for *Allolobophora* sp. and the larvae of an undetermined blow fly.

<center>3</center>

Porcellio scaber, a species of sow-bug, or wood louse, very common on the Pacific coast, is a typical symmetrical isopod with a pair of compound eyes set far apart in the head segment, and two pairs of antennae, of which the second antennae are conspicuous tactile organs, restlessly active during locomotion. The subequal walking appendages and the body in general are also sensitive to contact stimuli. Of other sense organs it is unnecessary now to speak.

---

[6] Since this was written, a paper by Dr. F. W. Bancroft, in the Journal for Experimental Zoology for November, 1913, appears definitely to have settled the question, for Euglena at least, in the affirmative.

During the day *Porcellio* is usually found under stones, logs, rubbish, in dark cellars, and various other sorts of cover from the light of the sun. Correlated with this habit is a definite negative phototropism.

In our first experiments, this phototropism was more or less masked by large individual differences in sensitiveness to light, and the apparent indifference of many individuals to light coming from incandescent bulbs placed directly in front of them. Later we discovered that the locomotion of many such indifferent individuals could be controlled with great definiteness by holding an incandescent bulb behind them, as they marched over a dead black table top, and moving it to one side or the other. Under these conditions—Mazda bulbs of both 25 w. and 60 w. were used—the organisms would move away from the light with the precision of a boat answering the helm. They could be guided in circles, in spirals, in courses that were directed, now to the right, now to the left, at the will of the experimenter.

That the eyes were the organs responsive to light was demonstrated by blinding them with a mixture of charcoal and glue. Individuals with the right eye blinded reacted to light from the left only; when the left eye was blinded light from the right was alone effective; when both eyes were blinded the individuals thus treated were indifferent to light from any direction.

4

Porcellio responds not only to changes in the direction of light. Exposure to light stimulates into activity animals that in darkness are quiescent; though sudden changes in intensity of illumination may produce inhibitory effects. Individuals vary considerably in their responses to these and all other types of stimulation. Marked differences may exist between individuals of the same size and apparently the same age; also between the reactions of the same individual at different times. Age differences are frequently connected with different reactions. Very young, unpigmented individuals are more responsive to directive stimulation than old. It is the rare exception for them to fail to respond, although adults are not uncommonly refractory. To sudden changes in intensity of light, however, old react at least as sensitively as young. In this connection the following case may be cited.

A female with a full brood pouch was placed in a Petri disk, round and round which she proceeded to move in the light of a 25 w. tungsten bulb. Many times when she was facing the light, the latter was turned off. Invariably she came at once to a dead stop. Only occasionally when the light was turned off while she was facing *away* from it would she react similarly; being obviously less responsive in such cases. Sudden *increases* of intensity, (i.e., when the light was turned on) always produced definite inhibition of locomotion.

One of the brood of this female responded but rarely to sudden increases of intensity when facing the light, not at all to sudden decreases and never while going away from the light.

The fact that young are more readily directed in locomotion by light while they appear to be at least no more sensitive than adults to sudden changes in intensity of light. suggests the possibility of two mechanisms governing the two types of reaction. There is a wide variation in the responsiveness of adults to sudden changes in intensity, however. The problem presented here will be investigated further.

<div align="center">5</div>

Though the eyes of *Porcellio* are sensitive to light, their power of forming images is approximately very small. Totally blind individuals avoid obstacles with the ease of normal individuals. When the second antennae of either are removed, however, they often bump squarely into obstructions, avoiding them only after contact through legs or body. The importance of the second antennae is emphasized by their constant activity during locomotion. when, by a rapid succession of tappings on the substratum, and wavings in the air, they explore the region immediately to the front. The usual random movements that are made by the anterior end of the earthworm and blow fly larvae are in *Porcellio* restricted to these mobile antennae. Since the head segment of *Porcellio* does not move perceptibly from side to side, it is only necessary to amputate the second antennae to eliminate what correspond to the usual random or trial movements in earthworm and blow fly larvae.

Such an operation was made in several cases. It was soon found, however, that, with or without the second antennae, *Porcellio* responded to photic stimulation under the conditions

of our experiments with unequivocal, definite, tropic reactions. So the operation was discontinued as useless. In later experiments on blow fly larvae and Allolobophora, the same definite tropic reactions were observed.

<div align="center">6</div>

For the sake of clearness it should be pointed out not only that "random movements" and "trial movements" are expressions not always used in the same sense, but that apparently spontaneous random movememts may be controlled to some extent by the environment. The exploring movements of the second antennae of *Porcellio* are largely initiated and regulated by internal conditions; this is evident especially when environmental conditions remain constant. A slight change in the texture of the substratum, however, may produce marked changes in its behavior; in the absence of the antennae, contact differences may make themselves effective upon the path of locomotion through the legs or body. It is a truism that the behavior of an organism is a resultant of the responses to all simultaneously acting stimuli. A movement initiated from within, when the organism is exposed to various contact stimuli, may frequently be modified if not entirely inhibited by them. The same may be said of movements initiated from without.

It happens, therefore, that so-called "trial" movements in *Porcellio* and blow fly larvae and earthworms vary their character and intensity with circumstances. They may be so augmented by external stimuli as largely to obscure the tropic reactions which under other conditions are readily perceived. The source of the external stimulation may, however, be very inconspicuous. This was especially true in the case of a blow fly larvae that had been traveling away from the light in a direct course with very slight lateral movements of the anterior end. Suddenly the anterior half of the body was lifted and swung from side to side, up and down, in irregular movements of large amplitude that continued for several seconds. The cause of this change in behavior was finally discovered in a bit of filament from the paper substrate that had been picked up and was adhering to the anterior end. For the time, these vigorous "trial" movements, initiated probably by internal conditions but owing their conspicuous characters to contact stim-

uli, effectively masked the heliotropic movements so apparent under other conditions. Similar pronounced movements were frequently seen when a' larva, crawling out over the edge of the glass plate on which it was being observed, would free the anterior third or half of its body. It would then wave this free portion about much in the manner of a leech. Dryness of the substratum may produce similar effects. Such behavior suggests the probability that even the small random or trial movements of the anterior end that ordinarily accompany locomotion are controlled—their amplitude, perhaps being determined—to some extent by contact stimuli.

7

It is possible then, to distinguish between random movements that have no connection with photic stimulation, and movements that Mast calls trials, but are conditioned by photic stimulation. For convenience in further analysis, it will be desirable to distinguish between two groups of reactions thus conditioned. In the one may be placed reactions to high intensities of light, such as direct sunlight; in the other, reactions to lower intensities. All of these reactions are regarded by Mast as trial movements similar to the avoiding or shock reactions of the lower organisms. The reactions of the second group—however we may view them as " trials "—do indeed resemble those reactions of such a form as *Euglena*, that are in the *same general direction* with reference to the source of light. The reactions of the first group, however, occur *either toward or away from* the source of light. They are non-directive with reference to the source of light.

This distinction is emphasized by our observations on earthworms and fly larvae. When light was allowed to fall from the side upon the extended anterior end of either of these forms, the first movement of the anterior end was for certain intensities of light *away from* the latter, whether directed toward or away from the light, when exposed.

8

To eliminate as far as possible all non-directive reactions from the behavior of *Porcellio* to light, in order to discover any directive, tropic movements of orientation that might be present, we adopted two very simple methods. The first consisted in

exposing sensitive individuals suddenly to lateral illumination. The individual to be observed was placed on a smooth dead black ground, in a dark room. When its orientation had been accurately determined by means of a 25 or 60 w. tungsten bulb a few inches behind it, away from which it was moving, or a distant light in the ceiling, another tungsten bulb of either 25 or 60 w. and at different distances varying between 20 and 40 cm., was suddenly turned on, so that its light should strike the animal from the side at an angle as near ninety degrees as possible. Sometimes at the instant the lateral light was turned on, all other lights were extinguished; at other times, they were not. In both cases, the direction, with reference to the lateral light, of the first movement of the organism out of its course was determined.

These experiments, simple as they were, gave results that were strikingly definite and convincing. *Almost invariably* the first movement was *away from* the lateral light. The reaction was sharper, on the whole, when light came from the side only. To the 60 w. light, at 40 cm., the response was more definite than to the 25 w. light at the same distance. But the reaction was unmistakably negative within the limits of variation of lighting and distance mentioned. A significant feature of the results was the ease with which they were obtained and the simplicity of means employed.

It must be remembered that all individuals are not equally sensitive to light. But the consistency with which many individuals turned *away* from the light, whether the latter was on one side or the other, left no room for doubt that the reaction was *forced in a definite direction*.

9

The second method of experimentation, equally simple, was determined by the fact that many individuals responded more readily to light coming from behind than from in front of them. The following series of observations taken one afternoon are not selected, but indicate the reactions of the first individuals tested.

The lamps used in these experiments gave a source of light 4 to 5 cm. in diameter. This fact it is important to keep in mind when considering the definiteness of the responses of *Porcellio* for the smaller angles of incidence recorded in the tables. For

instance, at 70 cm. from the organism the light used possessed an angular diameter of 4°; at 36 cm., 7°; at 50 cm., 6°; at 15 cm., 16°.

I. A 25 w. tungsten bulb gave the light at approximately 70 cm. from the animal. The latter was a medium-sized adult. Since the sexes respond similarly to light, no account was taken of sex in this and the following experiments. Having determined the orientation of the animal by means of a 60 w. bulb behind it, this bulb was turned off as the 25 w. light was flashed upon it, from in front, striking the eyes of the animal so as to make an acute angle with the axis of the body.

Trial 1, Light 35° to left ; response to right.
"   2,   "   15° "   "   ; animal stopped, wavered, and turned to right.
"   3,   "   70° "   "   ; animal stopped, then turned to right.
"   4,   "   60° "   "   ; response to right.
"   5,   "   10° "   "   ; animal stopped, moved forward, then to left (toward light).
"   6,   "   5° "   "   ; same as 5.
"   7,   "   3° "   "   ; same as 5.
"   8,   "   5° " right; animal turned to left.

These trials show a tendency in the organism to turn away from the light, the direction in which the turn is made depending upon the position of the light and the angle at which it strikes the eyes; there is a stronger tendency to turn to the left than to the right, but this is overcome when the light from the left strikes the eyes at an angle with the body axis of 15° or more.

The same tendency to turn more readily to one side than to the other is seen in the next series; though here the organism turns more readily to the right.

II. Another individual. Lights as in Series I.

Trial 1, Light 10° to left,   36 cm. distant. Response to right.
"   2,   "   35° "   "   36 "   distant. Response to right.
"   3,   "   5° " right, 36 "   distant. Response to right.
"   4,   "   12° "   "   36 "   distant. Response to right.
"   5,   "   5° "   "   70 "   distant. Response to right.
"   6,   "   5° " left,   70 "   distant. Response to right.
"   7,   "   45° " right, 70 "   distant. Response to left.
"   8,   "   30° "   "   70 "   distant. Response to left.

As in the first series, the organism turns *away* from the light, either to the right or left, when light strikes it at an angle greater than a certain magnitude, in this case between 12° and 30°. When the light strikes it at an angle of 12° or less, the organism

turns *toward* the light in the definite turning movement that ultimately carries it *away* from the light.

The two series of trials just presented suggest a difference in the sensitiveness of the two eyes to light. Tests of each individual by means of a light shining upon it from behind, fully supported this view. The first individual was guided without fail to the left when the light came from behind at a small angle to the right; but the same individual did not respond with such definiteness to light coming from behind at a similar angle to the left. These statements will apply equally well to the second individual, if the directions are reversed.

III. Another individual, young, unpigmented. Lights as before.

```
Trial 1, Light 25° to right, 36 cm. distant; response to left.
  "   2,    "     3°  " left,  50  "   distant; response to right.
  "   3,    "     3°  "  "     50  "   distant; response to right.
  "   4,    "     5°  "  "     50  "   distant; response to right.
  "   5,    "     5°  " right, 50  "   distant; response to right.
  "   6,    "     5°  "  "     50  "   distant; response to left.
  "   7,    "     8°  "  "     50  "   distant; wavered, then left.
  "   8,    "     5°  "  "     50  "   distant; wavered, then left.
  "   9,    "    15°  "  "     50  "   distant; response to left.
  "  10,    "     5°  "  "     50  "   distant; response to left.
  "  11,    "   en face,       50  "   distant; toward light, then left.
  "  12,    "     5°  "  "     35  "   distant; response to right.
  "  13,    "     5°  "  "     50  "   distant; response to left.
  "  14,    "    10°  " left,  50  "   distant; response to right.
  "  15,    "     8°  " right, 50  "   distant; response to left.
  "  16,    "    10   " left,  50  "   distant; response to right.
  "  17,    "     5°  "  "     50  "   distant; stopped, then to left.
  "  18,    "    10°  "  "     50  "   distant; response to right.
  "  19,    "   en face,       50  "   distant; wavered, then to left.
  "  20,    "     5° to right, 50  "   distant; response to left.
  "  21,    "     5°  "  "     50  "   distant; wavered forward.
```

This series brings out the fact that although the individual responds to light as an approximately symmetrical animal, its reactions lose precision when the light rays fall upon it from the front at very small angles (e.g., five degrees or less) with the axis of the body.

The following record of another individual bears directly upon this point. Preliminary tests showed that this individual, almost symmetrically sensitive to light, responded toward the right a bit more readily than toward the left. A 60 w. Mazda lamp was used, about 15 cm. in front of the animal, a given number of degrees of arc to the right or left as the case might be.

Light 5° to right; 5 trials. Responses to right, 2; left, 3.
"   5° " left;   6   "   "   "   " 5   " 1.
"   10° " right; 6   "   "   "   " 2   " 4.
"   10° " left;   5   "   "   "   " 4   " 1.
"   15° " right; 7   "   "   "   " 0   " 7.
"   15° " left;   6   "   "   "   " 6   " 0.
"   20° " right; 6   "   "   "   " 0   " 6.
"   20° " left;   5   "   "   "   " 5   " 0.

It appears from these observations that while the initial locomotor response might be toward the light in a small percentage of cases, such responses occurred only when the rays of light made an angle of less than 15° on right or left with the body axis. This is not surprising when one remembers the large angular diameter of the source of light in this experiment. Beyond 15° the response was consistently away from the light. Further, in the few cases when the response was at first toward the light, the animal continued to turn toward the same side until it ultimately moved away from the light. These exceptional cases, then, only emphasized the negative phototropism of *Porcellio*.

SUMMARY

1. Reasons are given for considering every orienting reaction phototropic whose direction is predictable in that it bears a definite relation to the source of light. *Euglena viridis*, species of blow fly larvae and earthworms, and *Porcellio scaber* exhibit reactions of this type, which is not satisfactorily interpreted by the method of trial.

2. *Porcellio* is easily guided in any desired direction by changing the direction of light falling on it from behind.

3. The first locomotor movement made by *Porcellio*, when exposed suddenly to light striking it at an angle of 90° with the major axis, was *away from* the light.

4. The same pronounced negative reaction followed sudden exposure to light from the front at angles between 90° and 15°.

5. When exposed suddenly to light coming from the front at angles less than 15°, *Porcellio* moved with less consistency away from the light; but the reactions were, on the whole, markedly negative. This lack of consistency was referred partly to the relatively large angular diameter of the source of light, partly to demonstrable inequalities in the sensitiveness of the two eyes of certain individuals to light.

MALE DOVES REARED IN ISOLATION

WALLACE CRAIG

The University of Maine

Eight of my Blond Ring-doves[1] have been reared in isolation, being removed from their parents after the age of weaning but long before the age of maturity, and being brought to maturity in cages where, though they could sometimes hear other doves, they could never touch nor see them.   The original intention was to rear each dove out of ear-shot as well as out of sight of all others of its species; but since this would require the keeping of each dove in a separate building, with a quarter-mile or more between buildings, it was found to be impracticable.   Of the eight doves reared in isolation, the present article will give the history of three males, Jack, No. 22; Billy, No. 23; and Frank, No. 30, and brief mention of the fourth male, No. 39:

Jack, No. 22.   Hatched July 17, 1907.   Removed from his parents August 17, his 32nd day.

Throughout the autumn and early winter this bird cooed very little.   But about the first of February there began a remarkable development of voice and social behavior.   The dove was kept in a room where several men were at work, and he directed his display behavior toward these men just as if they belonged to his own species.   Each time I put food in his cage he became greatly excited, charging up and down the cage, kahing[2] and bowing-and-cooing to me, and pecking my hand whenever it came within his cage.   From that day until the day of his death, Jack continued to react in this social manner to human beings.   He would bow-and-coo to me at a distance, or to my face when near the cage; but he paid greatest atten-

---

[1] For a general account of the social behavior and life-history of this species, see Craig, W., The Expressions of Emotion in the Pigeons.   I.   The Blond Ring-Dove (*Turtur risorius*).   Jour. Comp. Neurol. and Psychol., 1909, Vol. 19, pp. 29-82.

[2] " Kah " is the name I use for the well-known cry, sounding like a laugh, which has won for this dove its specific name *risorius*.

tion to the hand—naturally so, because it was the only part with which he daily came into direct contact. He treated the hand much as if it were a living bird. Not only were his own activities directed toward the hand as if it were a bird, but he received treatment by the hand in the same spirit. The hand could stroke him, preen his neck, even pull the feathers sharply, Jack had absolutely no fear, but ran to the hand to be stroked or teased, showing the joy that all doves show in the attentions of their companions. Growing up in isolation from all companions of his own species, he gave himself completely to the companionship of human beings.

July 7, 1908, when Jack was almost a year old, I put an end to his isolation. I tested him (and Billy also) with birds of different kinds, to see if he would choose his own kind. The results were positive, but I have discovered a possible flaw in the conditions of the experiment. When I have pigeons of several species, as I have not now, I shall repeat this experiment on species recognition after rearing in isolation.

July 12, 1908, I placed Jack's cage beside the cage of dove No. 19, a virgin female, in order that they might become acquainted. They had seen each other a little during the previous few days. When the cages were placed side by side, each dove at once showed excited interest in the other, and the female repeatedly gave signs of a desire to mate with the male.

July 14, I let Jack into the cage of the female, by opening the doors between the cages, this being the first time since his infancy that Jack has come into contact with another dove. He went into her cage without hesitation, and soon began to peck and chase her. He had long been accustomed to pecking my hand, but now when he made his first peck at a dove and his bill closed on the feathers, he stopped in evident surprise and did nothing more for a few seconds. But ever after this first experience, he tugged and shook the female dove's feathers as an old male does.

On this first day of contact his attitude toward the female was that of cruel pugnacity, never showing any considerable tenderness or eros. I was obliged to close the doors, preventing contact of the two birds, out of mercy to the female. Next morning the two were lying as near together as they could, in their separate cages, in apparent love and friendship. Never-

theless, after four more days of such acquaintance, when on the afternoon of July 18th I again let him into her cage, he was again cruel to her, though he did also nest-call to her. I closed the doors between them after ten minutes. A main reason to be given for Jack's cruelty to the female, is that he regarded me, the human being, in some degree at least, as his mate; the female dove was, therefore, in so far regarded as an interloper, to be attacked and driven away.

But from July 14th, when Jack first came in contact with a dove, he began to divide his attentions between human beings and doves. He ceased to kah and bow-and-coo to me; though until the day of his death he remained as tame as ever, and always pecked the hand that was put in his cage.

In regard to the sexual reaction, Jack's behavior was most remarkable. He never showed this reaction at all, so far as I observed, until he came into contact with another dove. And then he showed (at first) no tendency to unite with that dove. But it appeared nevertheless that the dove had aroused his sexual impulse; for on July 18th, when food was put in his cage, Jack pecked the hand that was putting in the seed-cup, then assumed that peculiar erect posture which precedes copulation, jumped on the hand, and began to go through the movements of copulation, an act he had never done before.

" July 19, 10:40 A. M. I open the doors, letting male into cage of female. He chases her savagely, bites, pulls feathers. After one minute he goes to nest-calling, but soon savagely chases her again.

" He then bows-and-coos a great deal to *me*. Also, he makes a curious little flight upward, and a feint as if to alight on back of female. I suspect that he is seeking copulation, but is seeking the hand as his stimulus; so I put hand in the cage, and find that my surmise is correct. He does not tamely jump on the hand, he flies on it; then he begins to go through the movements of the sexual reaction. Soon as this was put beyond question, the hand was taken away from him."

The male then went back to the nest site, sounded the nest-call, allowed the female to come to him and caress him, preened her head a little in return, and thus worked himself up to another crisis of excitement. When the crisis came, he again made not the slightest attempt at intercourse in the normal manner, but

made frequent *flights* upward in the direction of the female, or in other directions, exhibiting high excitement and some bewilderment. "When he flies up he always hovers, sometimes over the female, sometimes over he knows not what." Sometimes he tries to reach me, sometimes not. After such an abortive attempt at venting his passion "he chases the female as savagely as ever, or more so, even jumping on her back. Then they nest-call again. Then he chases her again." They reach the stage of attempting to bill, which stimulates the male so that he dashes up again in his passionate, hovering flight. "Thus they repeat and repeat."

July 20, both forenoon and afternoon, I let the birds come together for a time, with the same results.

July 21, I let the birds come together, and put a nest in the cage. Once when the male was in the nest and the female at the other end of the cage, he "nest-calls to her a few times, then suddenly he lifts himself and glares at her, chases and worries her a long time, even pulling feathers out. Four times during this onslaught he makes one of his peculiar passionate flights; the first three times the flight was toward female, as if with vague notion of alighting on her; the second time he did alight on back of her neck but did nothing more. The fourth time, in contrast, was a flight high (nearly two feet?) in air."

The same day the female began to sit in the nest, preparing to lay. This fact checked the male somewhat in his activity toward her; as it does every male. But the effect on this male was interesting, thus: "Male jumps toward female, then turns toward me, then pecks female, then runs toward me. Gives it up. Soon at it again; drives female off nest and pecks her many times, then tries to get to me, thus back and forth for long period. Apparently it was his failure to reach me that drove him each time to the female; then his contact with her restimulated him so that he wanted to come to me."

The first experience with a nest I shall describe in another article, dealing with many birds. The first egg was laid July 22. Under the influence of the nest, the egg, and the sitting female, Jack gradually succumbed to the brooding implulse and ceased to show erotic activity. All through his brooding he showed a tendency to come off the nest toward any human

being who came near, partly in friendship, partly in anger in defense of nest. But even in showing hostility toward us, Jack reacted toward us, not as he would toward other enemies such as dogs and cats, but with the behavior which a normal dove would show toward intruding members of its own species.

The eggs were of course infertile. At the end of the brooding period I separated the pair, and kept Jack in isolation again through the winter. When the spring awakening came upon him (spring of 1909), he directed his display at first to no fixed and definite objects, but a little coaxing started him bowing-and-cooing to human beings, and soon he cooed to us a great deal, though not, I think, with quite the same earnestness as in his first spring season when he had had no experience with a dove mate.

July 5, 1909. For the first time since the previous year, I placed him where he could see another dove—this time dove No. 20, an old, experienced female. The next day he began to show eagerness, evidently erotic, to reach human beings. On July 11th he tried to copulate with the hand. On July 15th, on two occasions, I saw him trying long and hard to accomplish the sexual act on one of the perches of his cage.

July 22, 9:15 A. M.-12:30 P. M. I opened the doors, allowing Jack into the cage of the female. He made no attempt to copulate with her; but at 11:30 A. M. I saw him, by himself, trying as on July 15th to accomplish the sexual act on a perch.

2:15 P. M. Again I open the doors. Soon I see the pair billing. The female, an old experienced bird, takes the lead, assuming the copulation posture many times, but the male does not mount.

2:35. They try again. The male mounts, but fails to accomplish the act.

2:43. They try again. The male does not mount.

2:50. The male tries to get out toward me.

2:58. After long preliminary the male mounts, but too far back and to one side, and he soon dismounts. They bill again, then give it up.

3:07. After billing male begins to go through the sexual reaction on the perch. The female interrupts him by commencing again her begging reaction.

3:10. The male tries to get out toward me.

3:35. They try again, not successfully, I think. After fur-
ther preliminary reactions, the male makes a slight attempt
to perform the sexual act on the perch, but soon desists.

3:50. They make an attempt which is apparently successful.

After this the male quickly learned to copulate with the
directness and efficiency which characterize experienced doves.

He went through the process of incubating the eggs and
brooding the young. And in March, 1910, he fathered another
brood. But he was always liable to leave the eggs or the young
whenever a human being came into the room. He was, there-
fore, a very poor sitter and a poor brooder, and his young were
not well fed. Since I was hard pressed for room to keep my
birds, I felt I could not keep a bird which was worthless as a
parent: I gave Jack to the University of Maine, and he was
killed and mounted for the museum.

Billy, No. 23. Hatched September 23, 1907. Father re-
moved October 1. Young removed from mother October 29,
his 37th day.

In order to test whether the development of voice in the
young dove is at all due to exercise of the voice, I endeavored
to prevent this bird from kahing and cooing. I kept him in a
room by himself, with a brick apartment building between him
and my other doves. and with the room darkened, so far as
possible, at night. Kept so for months, he was far more silent
than other doves, but he did coo a little, prompted evidently
by internal stimuli. On January 6th I took him to a room in
the University of Chicago where he could hear one other Ring-
dove (Jack), and sometimes Common Pigeons; still he cooed
but little. The comparative lack of vocal exercise did not, in
any way that I could observe, retard or impair the development
of his voice.

His display behavior appeared very suddenly; so far as I
observed, it appeared within three days, March 2, 3 and 4.
Billy gave himself to human companionship as heartily as Jack
had done, losing all fear of human beings, and showing all the
signs of excitement and joy in our presence.

After his long period of isolation, Billy was introduced to
other birds on the same day and under the same circumstances
as Jack (see page 122).

In 1908 I did not give Billy an opportunity to mate, as I did Jack, but kept him in a cage by himself. He could always hear other doves about him, but most of the time he was unable to see them. He continued as familiar as ever with his human companions. Even through the autumn he bowed-and-cooed to us whenever he was enticed to do so. His spring awakening began about the 20th of January, and became just as intense as that of the year before, for when his spring fever was at its height he cooed almost incessantly from the time the window shades were rolled up in the morning until the lamps were extinguished at night.

After three months of excitement, however, he seemed to be tiring out. In the month of May he became much more quiet, and toward the end of that month he acted as if he wanted to sit. We gave him a little straw, and he tried to make some use of it, so a few days later, about May 29, we gave him a nest containing an egg. He took quickly to the nest and sat faithfuly on the egg all day, leaving it only to roost each night.

June 1. Fearing that his health may suffer from lack of exercise, I decide to put an end to his sitting. So at 1:30 P. M. I quietly remove the egg from under him. He sits on unconcernedly.

June 4. Though the egg was removed three days ago he still continues to sit. For the first day or two he sat on the empty nest, but now he sometimes sits on the floor, hooking his bill around little pebbles or such objects and pushing them under him as 'f they were eggs. He is as savage as a broody hen.

June 11. We took the nest out some days ago, but he continues to try to sit. He is still insanely combative.

June 18. I bring Billy into the company of another male dove (Frank), allowing him not only to see the other dove, but to come into contact with him and fight. This puts an end to his tendency to sit.

Billy was not given opportunity to mate until October 8, 1910, when he was more than three years old. On October 8 and 9 I allowed him to enter the cage of female No. 19 (now a bird of considerable breeding experience), whose cage had long been beside his for preliminary acquaintanceship. I watched the behavior of the pair continuously (closing the cage door between them whenever I could not be present), but I kept out

of sight myself, in order that Billy might not be distracted by
my presence as Jack was.

October 8.   Billy was very cruel to the female.

October 9. . Little or no cruelty.   He responded to the female
with mating and nesting behavior.   Several times he showed
sexual excitement and a desire to fly on something, yet no ten-
dency to mount the female, until—

3:22 P. M.   Female comes in again and flies up beside male,
and, on her initiative, they bill two or three times.   She then
takes the copulation posture, maintaining it steadily, close
beside the male and parallel to him.   This evidently gives the
male just the needed stimulus, for after just the normal pause
he mounts.   He mounts, however, obliquely across her body,
and goes through his sexual reaction in that sidewise position,
not effecting union with the female.

On October 10th I was not able to be with the birds, and by
mistake I left the door open so that they had free access to each
other.   During that day Billy evidently learned to mate in a
manner almost normal; but for a long time (for years, and I
think in some degree to the present day) he persisted in a habit
of omitting the preliminary ceremony of billing, flying without
warning on the back of the female.

Billy now has had much experience, not only with a mate
and young but also with a small flock of doves; his attention
has thus been drawn strongly toward his own species, people
have been kept away from his cage to some extent, and he has
practically given up his abnormal attachment to human beings.
For a long time he continued to react with more or less excite-
ment to our presence, especially to our hands, but now no such
tendency is noticeable.   During his almost three years of isola-
tion he developed a most truculent disposition, partly perhaps
because he was teased by some persons—this is probably one
reason why he so readily gave up human companionship.   After
a long period of peaceful life with mate and young, his disposi-
tion has become very mild.   He is a good sitter, brooder, and
feeder of young.

Frank, *No*. 30.   Hatched July 24, 1908.   Put in isolation
about November 10, his 110th day (a late date, due to lack of
facilities).

The history of Frank is in general like that of Jack and Billy, but with many differences of detail.

Jack and Billy had been kept in a well-heated room, where several students were at work daily, both forenoon and afternoon. But Frank was kept in a cold room, in the climate of Maine, where he saw no one except myself, and saw comparatively little even of me. These conditions probably account for the fact that Frank was for a long time a silent and shy bird. He never bowed-and-cooed, so far as I observed, until April 8 or 9, which was just after a warm wave had struck the locality, bringing, as it happened, a great wave of migrant birds. On April 10th Frank bowed-and-cooed a good deal. But after a few days he became quiet, and I did not hear this display coo from him again until about May 8. In bowing-and-cooing he always stood at the same point on his perch, facing toward a certain corner of the room, and thus was probably directing his display to some object, though I did not discover what that object was. He never directed his bows to me until a change came over him which I shall now recount.

Since the bird was uncomfortably shy and afraid of human beings, I began about the last of April to starve him mildly and compel him to feed from the hand. He quickly learned to take his seed in this way, and he always jumped on the hand—but not in a friendly manner, often with a few sharp pecks or a blow of the wing. But on May 11th, after jumping on the hand as usual he stood still a few seconds and then, quite unexpectedly, he gave the sexual reaction of the male.

As soon as the bird had performed this act for the first time, his whole bearing and demeanor changed so markedly that he looked like a different individual. Before, I had mistaken him for a female. Now, his form, his pose (tending toward the charging attitude), his movements, and the glare of his eye betokened the male. He kahed and bowed-and-cooed to the hand, and pecked it in amorous fashion, whereas before he had always pecked in an unfriendly manner. And he allowed the hand to preen his neck and even pull the feathers.

From that date on until the next change in him (June 17th) Frank exhibited almost daily the sexual tendency, but he gradually ceased to bow-and-coo, and he relapsed largely into the demeanor of an immature bird.

June 17. I put his cage beside that of Billy, thus allowing Frank to see another dove for the first time since he was put in isolation. The sight of the other bird and the sound of his voice at once wrought a change in Frank like the change he had temporarily undergone on May 11th, but in this case the change was far greater, and was permanent. He was now in a few moments transformed from the meek young bird of indeterminate sex into the strong, aggressive adult male. I should not have recognized him as the same bird. He seemed to become so much larger than before, that it was hard to believe there was not an actual increase in size. Now he not only bowed-and-cooed, uttered the kah of excitement, and charged up and down the cage, but after a half-hour of such display he assumed the nest-call attitude and gave the nest-call coo, which I had never known him to do before.

June 18 and 19. I allowed these two males to come together. They fought with might and main, and Frank worsted Billy.

After these experiences with another dove, Frank readily and persistently bowed-and-cooed to my face and to my hand, as he had not done before. He continued for a long time, even after he was mated, to jump on the hand that fed him, so persistently that he was a nuisance. But though he jumped on the hand he did not show sexual behavior toward it, not after his first contact with the feathers of another dove on June 18th.

July 5. I placed his cage beside that of a female dove. July 22, I opened the doors, allowing the two to come together. Frank showed a gradual leading up to the perfect mating behavior, similar to that of Billy, but more rapid. The most interesting feature was, that Frank sometimes turned from the female dove to bow-and-coo to me. Since then he has had much experience with doves, and has shown chiefly normal behavior. He maintained for a long time, as stated above, a habit of jumping on the hand. In 1910 he was taken from his cage and put, with other doves, in a large room where he ceased to come much into contact with people's hands, but came naturally into proximity with our feet; he developed that year a habit of bowing-and-cooing to one's shoe and then jumping on the shoe. This habit persisted in 1911, when I noticed that he reacted to tan shoes just as to black shoes, and he showed in many ways that he was reacting to the human being, even though his attention

was given chiefly to the shoe.   Last year and this year (1913)
Frank has been kept in small cages which are so arranged that
the hand does not need to be put into the cage to put seed in;
he has therefore had no contact with hands or shoes, and he has
seen much more of doves than of human beings: he has largely,
though not entirely, given up cooing to human beings.   When
I come near his cage, he still shows a desire to get out to
me, and jealousy of other doves in my presence.[3]   But he is a
successful mate and a good sitter, brooder, and feeder of young.

Dove No. 39.   Hatched July 14, 1910.   Put in isolation
September 26, his 75th day.   This dove took to human com-
panionship as did the other three.   He has not yet been al-
lowed into contact with his own species, but has been used for
an entirely different experiment which is not yet completed.

SUMMARY AND CONCLUSIONS

The history of these doves reared in isolation covers a wide
range of behavior, and many points of interest, from which I
select the following.   These conclusions will be confirmed and
amplified in other articles, one of which will treat of female
doves reared in isolation.

1. Four male doves were reared (after weaning) in isolation,
each being unable to see any dove companions.

2. All these doves were for a long time very quiet.   In the
case of Frank especially, the masculine display behavior did
not appear at all until he was socially stimulated; then the
display behavior appeared so suddenly as to transform the bird
in a few moments.   All four doves exhibited more or less of this
sudden development of behavior under the influence of new
social factors in the environment.

3. The various notes uttered by this species, and all accom-
panying expressive movements, developed in perfect form in
isolated individuals, showing that young doves do not need to

---

[3] August 18, 1913.   Today, due to an accident, Frank escaped from his cage.
I followed him with an open cage in which I sprinkled tempting seed, but could
not induce him to enter.   So I carefully approached him from below, and gently
raised my hand to catch him.   But he, seeing my hand come to him thus, began to
show some of the old fascination for the hand, and after several seconds he jumped
on my palm.   I quickly put my other hand over him, and he was caught.

learn the sounds[4] or gestures of their species by copying older doves. The vocal and gesture reactions are thus, in their motor aspect, very completely and definitely fixed by the innate organization of the nervous system.

4. On the other hand, the innate sensory inlets leading to these reactions must be very indefinite or flexible. For the doves give their cries and their gestures, now to one sense-object, now to a very different object, according to their experience. The four doves herein described, before they were allowed access (as adults) to their own species, gave their social reactions to human beings.

5. The three individuals which, after maturing in isolation, were allowed into the presence of their own species, associated with the other doves with every mark of eagerness and satisfaction.

6. These three gave up their intimate friendship for human beings. But they gave it up slowly and gradually, showing interesting divisions of attention between human companions and dove companions. If they had been encouraged to do so, they would probably have continued indefinitely to display to human beings; and even without special encouragement they remain, probably for life, exceeding tame, unafraid of the human species. This is one example of the importance and lasting influence of the dove's early impressions.

7. The sexual reaction of the male is, in its motor aspect, very completely and definitely provided in the innate nervous organization. But the innate sensory inlet to this reaction is not a complete sensory inlet; it is supplemented by experience.

8. The object to which the dove directs his social behavior becomes a symbol, in some cases it might even be called a fetich, to which he clings tenaciously, and to which he attaches a great complex of reactions. With all four of these doves, the human being became such a symbol; especially the human hand, and in the case of one dove (Frank) the shoe.

9. When a dove performs an instinctive act for the first time, it generally shows some surprise, hesitation, bewilderment, or even fear; and the first performance is in a mechanical, reflex

[4] It is true that each of my isolated males could hear other doves, but not such as to serve as a copy. For Jack and Billy could hear only each other; Frank could hear only the faint sound of doves cooing in a distant room; and No. 39 could hear no male dove but only a few females.

style, whereas the same act after much experience is performed with ease, skill, and intelligent adaptation. Thus even those acts which do not show improvement by the formation of associations, show improvement by *facilitation*.

10. In the case of an act in which instinct plays the greater part, and learning by experience the lesser part, especially when the result of experience is merely facilitation, the improvement in the performance of the act may be so rapid that it quickly leads to perfection. To detect the influence of experience or practice, one must observe from the very first performance of the act. To observe the very first performance of the social activities of the adult, one must rear the animal in isolation; and then allow it, while under close observation, to come into contact with another animal.

NOTES

HUNTER ON THE QUESTION OF FORM-PERCEPTION IN ANIMALS

H. M. JOHNSON

Assistant Psychologist, Nela Research Laboratory, National Lamp Works of
General Electric Company

In a recent interesting communication, Mr. Hunter[1] calls
attention to the need of sharper distinction between the study
of form-discrimination and that of pattern-discrimination. He
presents the thesis that animals below man and children between
certain ages "have only a more or less crude pattern vision,"
and are unable to discriminate forms. Mr. Hunter asserts that
there is no means of testing the validity of his belief unless the
surroundings of discriminable forms be changed, since the form
is "seen" with its surroundings and hence must be considered
as "part of a pattern." Even if no other objects are in the visual
field, the stimulus-object "is seen surrounded by the more or
less irregular outline of the field of vision, and so is again part of a
pattern." As a means of controlling the surroundings, he pro-
poses that after form-discrimination has apparently been estab-
lished, the alleys of the Yerkes experiment-box leading to the
stimulus-forms be enclosed with hollow cylinders or hollow
triangular prisms. Thus, he says, "it should be possible to
demonstrate experimentally whether the subject was reacting to
the 'forms' or to the 'patterns.'"

I am not clear as to two points raised in reading Mr. Hunter's
article. First, with reference to his proposed method of control:
Changing the enclosures of the alleyways would probably intro-
duce new olfactory stimuli, and if the animal should have to
touch any of the walls, the change would certainly introduce
new tactile stimuli. The introduction of any new stimulus-

---

[1] Hunter, Walter, S.: The Question of Form-Perception. This journal, vol. 3,
1913, pp. 329 ff.

factors frequently works serious disturbances. Quite recently
Mr. Lashley[2] reported disturbance from the first source. Mr.
and Mrs. Watson[3] obtained disturbance from both the first and
second factors. Other instances might be enumerated. Suppose
an experimenter should obtain failure to discriminate after making
such a change as Mr. Hunter suggests. Is there any means of
deciding whether the disturbance resulted from the change of
" pattern " or from the simultaneous introduction of other
novelties ?

Secondly, with regard to the necessity of any control, which
Mr. Hunter assumes: If a human observer place his eye at the
exit of the " home-compartment " of the Yerkes box, will not
a given form appear against quite different backgrounds and
behind quite different foregrounds according as it occupies the
right and the left positions respectively ? To the writer it does.
Since the stimulus-form is as effective in one setting as in the
other it would seem that we are justified in saying that the animal
is reacting to the constant form difference and disregarding the
variable pattern-difference of the stimuli; using the term pat-
tern-difference in Mr. Hunter's way.

---

[2] Lashley, K. S.: Visual Discrimination of Size and Form in the White Rat.
Ibid., vol. 2, 1912, pp. 310 ff.
[3] Watson, John B. and Watson, Mary I.: A Study of the Responses of Rodents
to Monochromatic Light, Ibid., vol. 3, 1913, pp. 1 ff. The disturbance referred to is
not reported, having occurred in the preliminary work. The writer received the
information directly from the authors and refers to it with their permission.

A DEFINITION OF FORM

HAROLD C. BINGHAM

Ellsworth College

Regarding separate studies in form perception by Lashley and myself,[1] the following criticism has been urged:[2] " Both series of experiments referred to above are concerned with *patterns*, not *forms*." " In problem boxes such as those described by Lashley and Bingham . . . the animal tested is confronted *not* by two " *forms* " corresponding to the configurations of the opal glass, but by such designs as are suggested in figure 1.
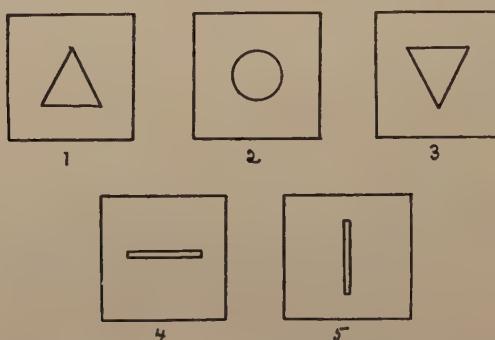

FIGURE 1. Reprinted from *Jour. Animal Behavior*, vol. 3, no. 5, p. 331.

The squares drawn in the figure represent the rectangular tunnels down which the animal goes in making his responses. What the animal sees is a triangle or a circle each in more or less of a square setting." In substance, the form is not without a perceptible environment and, therefore, is strictly a pattern.

Accepting the definition of pattern and conceding for the moment the definition of form urged by Hunter, I maintain that,

[1] Lashley, K. S. Visual Discrimination of Size and Form in the Albino Rat. *Jour. Animal Behavior*, 1912, vol. 2, No. 5.
Bingham, H. C. Size and Form Perception in *Gallus Domesticus*. *Jour. Animal Behavior*, 1913, vol. 3, No. 2.
[2] Hunter, W. S. The Question of Form Perception. *Jour. Animal Behavior*, 1913, vol. 3, No. 5, pp. 330–1.

136

under the conditions as described in my paper,[3] the visible stimuli
presented to the animals for discrimination were forms *not*
patterns.   On page 66 I state that the whole apparatus was set
up in a dark-room.   I follow this with an explanation of the only
sources of illumination.   On page 98 appears the plan of con-
trolling all light factors.   Now, in these conditions of control,
there is to be found a refutation of the point which Hunter
seeks to establish.   The rectangular tunnel, to be sure, remains,
but the perceptibility of the environment is wholly changed, if
not destroyed.   That the animals could not see the environment
is attested by the fact that they were frequently observed to
walk blindly into the confining walls.   Not all of the time was
the environment " darkened," but the control tests were always
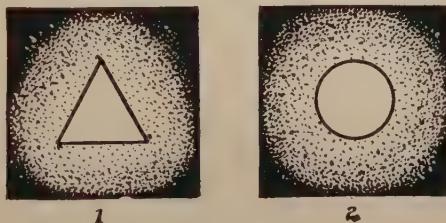
<center>FIGURE 2</center>

made to determine whether or not, among other factors, setting
was a factor in discrimination.

Figure 1 does not accurately illustrate the condition of the
stimulus areas.   With the introduction of a screen between the
general illumination and the electric boxes and with the re-
duction of the intensity of the source lights, a condition similar
to that illustrated in figure 2 appears.   In the compartment
where the triangle appears, the source light fails to illuminate
the corners of the tunnel, and so the perceptible portion of the
setting changes to a sort of circular form as in diagram 1.   About
the circular stimulus the visible setting is more nearly a perfect
circle as is shown in diagram 2.   Even if my apparatus offered a
possibility of pattern discrimination, my plan of control would
have made so variable the patterns confronting the animal that
they never could have served as a basis of discrimination.

Hunter has apparently missed one of the essential features of
the apparatus which was used in my study.   The dark-room

[3] *Op. Cit.*

apparatus allows the experimenter to control the conditions of
setting by means of artificial illumination. His criticism would
be valid for similar experiments conducted in natural and un-
controlled light. With the visual discrimination uninfluenced
by setting, the perception could not have been of patterns.

Another feature which Hunter has overlooked is one of method.
Referring to figure 1, he asks:[4] " If an animal is trained on dia-
grams 1 and 2, is it any wonder that he breaks down when con-
fronted by diagrams 2 and 3 ? " Assuming now that the animal
actually sees " a triangle or a circle each in more or less of a square
setting," no explanation is offered for the breaking ·down of the
discrimination when merely the size of the form was changed,
i.e., when the triangle of 1 was a circumscription or an inscription
of the circle of 2. (Witness table 8, series 12, 13 and 14, March
21-22, and series 10, March 28; also table 9, series 5, April 21).[5]

Now in these tests the patterns remained the same except in
size, but the reactions changed from a high percentage of cor-
rectness to a relatively low percentage.

Besides this mis-statement of conditions there is an obvious
lack of agreement in the matter of defining " form." The so-
called " abstract sense " in which I have used the term has called
forth objections.

In my study of form perception I was not concerned with genetic
phases of the problem. My task demanded an answer to the
question: Does the chick perceive forms ?[6] Consequently, it
makes no difference whether or not the conception of form, to
which I have given expression, is the result of development. One
might consider that phase of the subject, but in my problem I
was justified in determining whether or not the chick perceives
form in this " abstract sense."

Now if our animals fail to perceive circularity and triangularity
as such, there are several principles that we should not lose sight
of. In the first place, we should not try to excuse our animals
nor become over-dogmatic in theorizing about extraneous, or
even allied problems. We should accept as a fact the conclusion
to which the evidence points.

Moreover, we should seek to determine and define just what

[4] *Op. Cit.*, p. 331.
[5] *Jour. Animal Behavior*, 1913, vol. 3, No. 2, pp. 106 and 109.
[6] The task would have taken on other complexities had positive results been
secured in the initial problem.

elements our animals *do* perceive. In this task we need not speculate on the question whether such elements are logical or genetic precedents of form perception.

To avoid confusion, we should avoid the application of a multiple meaning to the same terminology. We should not attempt to simplify our definition of form so that this factor may be included in the animal's stock of perceptual experiences.

Finally, if we find that our animals have a power of discrimination which approaches form perception, but which is *not* form perception in the strict sense of the term, we should adopt a terminology to fit the special case; we should not enlarge the conception of the term " form " to cover the special case.

Perhaps " a more or less crude pattern vision " is the nearest approach to form perception that animals possess. At any rate, Hunter has done well in calling attention to the distinction between patterns and forms. However, our definition must not stop here. Two forms may be identical, but different in " shape." This would be the condition in Lashley's study. He used two identical forms in that both were rectangles 2 mm. by 60 mm. They differ in this respect: one is extended laterally thirty times as far as its vertical extension, while the other is extended vertically thirty times longer than laterally. Now this is a difference in " shape " of two identical forms.

Miss Washburn, in reviewing my study,[7] has failed to make this distinction between form and shape. She says: " Bingham's chicks discriminated between a circle and a triangle when the apex of the triangle was on top, but since this discrimination broke down when the circle was presented with a triangle whose base was uppermost, the chick failing to choose the triangle, Bingham concludes that the chick was not reacting to form difference, but to ' the unequal stimulation of different parts of the retina.' The reviewer would conclude rather that the chicks were not possessed of an abstract idea of triangularity. A triangle with apex up is a different form from a triangle with apex down: the two have in common only the abstract quality of three-sidedness. The perception of form, as distinct from an abstract idea of form, is based precisely on the unequal stimulation of different parts of the retina."

---

[7] Washburn, M. F. Recent Literature on the Behavior of Vertebrates. *Psychological Bulletin*, 1913, vol. 10, No. 8, p. 320.

It is not to be denied that a triangle with vertex up differs from a triangle with vertex down.   But we can scarcely say that they are two different *forms*.   They are both triangles; yes, more than that: they are equilateral triangles.   Where they differ is *not in form but in shape*.   When the extended base of the triangle is so placed as to stimulate the region of the retina which was formerly stimulated by the vertex of the triangle, a condition occurs similar to that pointed out regarding Lashley's " forms:" the forms remain identical, but the lines of maximum and minimum extension have interchanged.   This fact led me to conclude in my paper [8] that *the apparent reactions to forms are the result of keen perception of size differences*.   I might have said they are due to perception of shape differences.   The inversion of the triangle causes certain particular size changes—vertex or point interchanged with base or line—which causes a change in shape, but no general change of size since the area remains constant.   Similarly the factor of triangularity remains constant and the form is unchanged.   Not " the perception of form," therefore, but the perception of shape " is based precisely on the unequal stimulation of different parts of the retina."

Our definition, then, as separate from the distinction between forms and patterns, must draw a line between forms and shapes. Referring to the retinal area stimulated, there is form which is general, *e.g.*, triangle.   But there is a particular feature about this general distribution of light—it is equilateral, or isosceles, or right angled—viz., shape.   Forms are identical when their areas are equal and their general retinal distribution is similar. Shapes are identical when all extensions of the identical forms are equal and in the same relative directions.   Thus, the area remaining constant, either or both form and shape may change. The form remaining constant, the shape may change.   Change in form must always cause change in shape.

Subsequent studies in this field should not fail to consider the factors of " shape " and " pattern " in their relation to form perception.   Whatever system of control is adopted, such possible disturbances as these factors must be considered and, as far as possible, eliminated and isolated.   Unquestionably my final test for form discrimination by shifting the position of the form was a severe one.   Surely the factor of shape was a disturbing in-

[8] *Op. Cit.*, p. 110.

fluence. If, with all possible disturbing factors properly controlled, this test of shifting fail, form perception in the strict sense of that term can scarcely be said to prevail.

I have shown that the discrimination of patterns was impossible in my study. There was a possibility of discrimination on the basis of two other factors. One of the remaining factors was form: the other has been arbitrarily termed shape. The inverted triangle possessed a different shape but an identical form as compared with the upright triangle. The high percentage of correctness in reactions changed to a relatively low percentage with the inversion of the triangle. Obviously, then, form was not the basis of choice.

THE AUDITORY REACTIONS OF THE DOG STUDIED BY THE PAWLOW METHOD

SERGIUS MORGULIS

Biochemical Laboratory of Columbia University, New York

From the time the first review[1] of Pawlow's ingenious method in animal psychology was published in this country great progress has been made by the numerous students of Professor Pawlow which puts an entirely new aspect on the psychology of the dog. Unfortunately, we are not in a position at this moment to offer a further extensive summary of the results obtained by this method since 1909, but a brief review of the recent paper of Usiewitch,[2] concerning the auditory faculty of the dog may prove of interest to American investigators.

It will not be amiss to state succinctly for the benefit of those not familiar with the first article referred to, the principle of Pawlow's method, the minute analysis of the animal reactions performed with its aid and some of the broad generalizations regarding nervous activity deduced from those analyses.

It is a matter of common experience that the salivary reflex may be actuated by the mere thought or even remote suggestion of a delectable article, but it remained for Pawlow's unusual acumen to recognize in this trivial fact the means provided by nature for penetrating the hidden workings of the animal's psychology. The presence or absence of the salivary reflex informs the investigator of the organism's reaction to a given stimulus. The method, therefore, possesses all the advantages of being strictly objective, i.e., quite independent of the observer's interpretation or " persönliche Ueberzeugung," as the Germans name it.

Starting with the idea of the salivary reflex, it was a relatively simple matter to determine the flow of saliva both quantitatively

[1] Yerkes, R. M., and Morgulis, S. The Method of Pawlow in Animal Psychology. *Psychol. Bull.*, vol. 6, pp. 257-273, 1909.

[2] Usiewitch, M. A Physiological Investigation of the Auditory Capacity of the Dog. *Bull., St. Petersburg Military Medical Academy*, Vol. 24, pp. 484-502; Vol. 25, pp. 872-891, 1912 (Russian).

and qualitatively by a special adaptation of the Pawlow fistula method.   The duct of the parotid gland is exposed by an incision of the cheek and a permanent fistula or outlet to the exterior is made.   The saliva is collected in a tube where it can easily be measured.

Through persistent training the salivary reflex may become coupled with any desired stimulus which is frequently applied while the secretion of saliva is called forth by feeding the animal a powder consisting of meat and sugar.   After long continued repetition the application of the particular stimulus alone is sufficient to cause a normal flow of saliva.   This indirectly produced salivary reflex is what Pawlow terms a "conditioned reflex," and the success of the analysis of reactions is based upon the absolute specificity of the latter.   The ability of the animal to differentiate between gradients of various stimuli is measured by the changes registered in the fundamental salivary reflex.

What the experimenter achieves by patiently adhering to a prearranged plan happens in nature continuously.   The world of the individual is two-fold in its make-up.   Some of its elements act on the animal's receptors causing sensations by directly stimulating them, others exert an influence, thanks to a more or less temporary association with one of the fundamental or unconditioned reflexes.   In the function of the higher centers Pawlow distinguishes, therefore, two mechanisms; the mechanism of receptors ("analysers" in Pawlow's terminology) which is for sifting out and selecting from the mass of external stimuli and transforming them into nervous processes of purposeful reactions; the other mechanism is that of the transitory association or interlocking of the phenomena of the outside world with the organism's responses.   The latter is the mechanism of the conditioned reflexes in all its complexity.

One of the most important discoveries in the investigation of the conditioned reflexes is the fact that every receptor at first enters into temporary association with the salivary reflex by its most generalized activity, its more refined and subtle faculty of differentiation being involved only gradually and by a very slow process.   The intensity of an illuminated area becomes the cause of a conditioned reflex much sooner than the shape of that area.   Likewise, when the central portion of the receptor mechanism—which may be either in the brain or in the spinal cord—

is destroyed or injured this particular receptor loses its ability to form conditioned reflexes except by its primitive and generalized function. Animals whose optic centres have been injured can still form associations between stimuli of various light intensities and the salivary reflex, but not with stimuli from special groupings of light and shadow.

As regards the auditory reactions of the dog it has been discovered by the conditioned reflex method (Selionyi, Elliasson, Tichomirov, Babkin, Burmakin) that its auditory faculty is much greater than that of man. The dog perceives $\frac{1}{8}$ of a tone and appreciates tones of a frequency of vibration which is entirely beyond human reach. It was also discovered that the dog has an absolute memory for sounds, which probably, but very few of the most gifted musicians possess.

Usiewitch's particular problem has been to study the dog's reaction to an intermittent auditory stimulation with a view to determining its ability to differentiate time intervals. It is hardly necessary to describe his technique, which is essentially the same as already described in the review alluded to. The intermittent stimulation was produced by means of a metronome. The subject of these experiments, a large healthy dog which never had been used for similar tests before, was found to be totally indifferent to the metronome so far as its salivary reflex was concerned.

By persistent training a conditioned reflex has been established to the stimulation with 100 oscillations per minute of the metronome. The stimulation of intermittent sounds of such frequency called forth 6-10 drops of saliva every time. The interval between successive oscillations was then modified, the moment of the disappearance of the conditioned salivary reflex indicating the lowest limit of differentiation. Without going into any details of this most interesting investigation or quoting actual data, I will say that the dog could sharply distinguish the shortening of the interval by less than $\frac{1}{40}$-$\frac{1}{43}$ of a second. Indeed with the well developed reflex to the stimulation of 100 beats per minute a change of the rate to either 96 or 104 beats was immediately reacted upon by a marked diminution or even complete cessation of the flow of saliva.

Furthermore, Usiewitch brought out some very significant points with regard to the intermission between tests with the

established, standard stimulation, and some unusual stimulation. Thus, the dog is able to differentiate distinctly between 104 and 100 beats (standard) if the new rate is tested 10, 15, 45, or 60 minutes later. The differentiation is less certain after 18 hours of intermission and vanishes completely after a lapse of 45 hours.

In responding to various intermittent stimuli of unaccustomed frequency a remarkable regularity and uniformity stamps the results. Applied immediately after stimulation with the standard rate of oscillation it produces a distinct depressing effect on the salivary secretion in the first trial. During the subsequent few trials the conditioned salivary reflex increases considerably, then again diminishes to complete disappearance in further tests. These facts are very important because they offer a clue to the analysis of the phenomenon of inhibition.

This review purports to bring once more before the attention of American investigators the enormous value of this purely objective analytical method in animal psychology and to stimulate an active interest in the subject which should soon lead to a systematic investigation of the reactions of various animals by this method.